Recommendations for Endangered Species Act Section 7 Consultations Involving Plants in New Mexico

Version 1.0

Photo Credit: Daniela Roth 2013

Prepared By:

Institute for Applied Ecology

For:

U.S. Fish & Wildlife Service

New Mexico Ecological Services Field Office

May 2024

This publication was collaboratively developed by the Institute for Applied Ecology (IAE), the U.S. Fish and Wildlife Service (Service), and the Bureau of Land Management (BLM) in coordination with representatives from other Federal and State agencies. BLM (Energy Office Program and New Mexico State Office) funded and administered this project. IAE coordinated with agency biologists, reviewed and synthesized the best available relevant literature, and developed resources and workflows for streamlining Section 7 effects analyses. The Service's New Mexico Ecological Services Field Office (NMESFO) provided technical assistance and adapted IAE's work for publication.

Suggested Citation

U.S. Fish and Wildlife Service. 2024. Recommendations for Endangered Species Act Section 7 Consultations Involving Plants in New Mexico. May 2024 (Version 1.0). U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office, Albuquerque, New Mexico. vii + 68 pp. + 3 appendices

Version History

Version	Description of Revisions
1.0	First version, revisions not applicable.

Accessibility

Reasonable accommodations will be made to access this document. If you cannot fully access information within this document, please contact the U.S. Fish and Wildlife Service's New Mexico Ecological Services Field Office at nmesfo@fws.gov or (505) 346-2525 with your accommodation request relative to specific components of this document. We may provide the information to you in an alternate format.

Acknowledgements

We greatly appreciate the assistance of the following experts who reviewed our draft recommendations and/or provided helpful information:

- Katrina Adamczyk, Wildlife Biologist/Conservationist, New Mexico State Land Office, Surface Resources
- Cecelia Alexander, Botanist, BLM, Las Cruces District Office
- Janelle Alleman, Fish and Wildlife Biologist, Service, NMESFO
- Lauren Bansbach, Botanist, BLM, Farmington Field Office
- Will Barnes, Deputy Director, New Mexico State Land Office, Surface Resources
- Mike Beitner, Botanist, BLM, Farmington Field Office
- Amber Bishop, Wildlife Biologist, U.S. Department of Agriculture (USDA) Forest Service, Santa Fe National Forest
- Molly Boyter, Botanist, BLM, New Mexico State Office
- Creed Clayton, Supervisory Fish and Wildlife Biologist, Service, Western Colorado Ecological Services Field Office
- Julie Crawford, Plant Ecologist, Service, Arizona Ecological Services Field Office
- Zoe Davidson, Botanist, BLM, New Mexico State Office
- Jason Douglas, Senior Fish and Wildlife Biologist, Service, Arizona Ecological Services Field Office
- Melissa Fry, Fish and Wildlife Biologist, Service, NMESFO
- Kim Frymire, Fish and Wildlife Biologist (Plants), Service, NMESFO
- Jake Gottschalk, Fish and Wildlife Biologist, Service, Western Colorado Ecological Services Field Office
- Melanie Gisler, Director, IAE, Southwest Office
- Michelle Guay, Fish and Wildlife Biologist, Service, Southwest Region Headquarters Office
- Chuck Hayes, Supervisory Fish and Wildlife Biologist, Service, NMESFO
- Deb Hill, Rio Grande Basin Recovery Program Supervisor, Service, NMESFO
- John Kendall, Wildlife Management Biologist, BLM, Farmington Field Office
- Kathryn Kennedy, Regional Botanist, USDA Forest Service, Southwestern Region
- Timothy Ludwick, Supervisory Fish and Wildlife Biologist, Service, NMESFO
- Nik MacPhee, Botanist/Ecologist, BLM, Taos Field Office
- Nik MacPhee, Fish and Wildlife Biologist, Service, NMESFO

- Jodie Mamuscia, Deputy Field Supervisor, Service, NMESFO
- Melissa Mata, Supervisory Fish and Wildlife Biologist, Service, NMESFO
- Jessica Miller, Fish and Wildlife Biologist, Service, Arizona Ecological Services Field Office
- Richard Norwood, Information Coordinator/Data Manager, Natural Heritage New Mexico
- Megan Rabinowich, Ecologist, IAE, Southwest Office
- Lauren Rangel, Fish and Wildlife Biologist, Service, NMESFO
- Nathan Redecker, Natural Resource Specialist, BLM, New Mexico State Office
- Sam Reiss, Botanist, BLM, Carlsbad Field Office
- Aurora Roemmich, Botanist, USDA Forest Service, Lincoln National Forest
- Kyle Rose, Conservationist Manager, New Mexico State Land Office, Surface Resources
- Katie Sandbom, Fish and Wildlife Biologist (Plants), Service, NMESFO
- Shawn Sartorius, Field Office Supervisor, Service, NMESFO
- Adriano Tsinigine, Fish and Wildlife Biologist, Service, NMESFO
- Ashlee Wolf, Ecologist, IAE, Southwest Office
- Vance Wolf, Fish and Wildlife Biologist, Service, NMESFO
- Sarah D. Yates, Fish and Wildlife Biologist, Service, NMESFO

Table of Contents

List of Figures

List of Tables

Page intentionally left blank.

1 Introduction

The mission of the U.S. Fish and Wildlife Service (Service) is to work with others to conserve, protect, and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. Federal lands and authorities are essential to conserving America's biodiversity and natural heritage, and Federal agencies and their agents are empowered to steward these resources for the benefit of present and future generations. The Endangered Species Act of 1973, as amended (the Act; 16 U.S.C. §1531–1543), authorizes us to list, protect, and recover species at risk of extinction now or in the foreseeable future.

The purpose of the Act is to "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved, to provide a program for the conservation of such endangered species and threatened species" (16 U.S.C. §1531(b)). It directs all Federal agencies to participate in conserving plants and other species listed under the Act. Specifically, section 7(a)(1) of the Act charges Federal agencies to aid in the conservation of listed species, and section 7(a)(2) requires the agencies to ensure their activities are not likely to jeopardize the continued existence of Federally listed species or destroy or adversely modify designated critical habitat. Section 7(a)(2) guides us to consider the needs of listed species and the effects of our actions so that Federal actions do not inadvertently compromise the existence of, or our capacity to recover, listed species.

The provision under section 7 of the Act (Interagency Cooperation) that is most often associated with the Service and other Federal agencies is section 7(a)(2). It requires Federal agencies to consult with the Service to ensure that actions they fund, authorize, permit, or otherwise carry out will not jeopardize the continued existence of any listed species or adversely modify designated critical habitats. Under section 7(a)(2), a Federal agency or its designated representative determines whether their proposed projects may affect threatened and endangered species or designated critical habitat. Pursuant to section 7(a)(4), conferences are processes of early interagency cooperation for species that are proposed for listing or proposed designations of critical habitat. Conferences are required for proposed Federal actions likely to jeopardize proposed species or destroy or adversely modify proposed critical habitat. Throughout this document, we simply refer to consultations, listed species, and/or designated critical habitats, but we also mean conferences, proposed species, and proposed critical habitats, as appropriate. Service staff work with Federal action agencies and/or applicants to develop the documentation needed to initiate and complete consultations.

The section 7(a)(2) consultation process can take up to or exceed, depending on project complexity, the following timelines (also see Figure 1.1). The Service has 30 days to provide an official species list (50 CFR § 402.12(d)), and the action agency has 180 days from receipt of an official species list to complete a biological assessment (50 CFR § 402.12(i)), at which point the official species list expires, and a new list must be requested. However, these first two timelines are no longer limiting because official species lists can now be generated within a day, and action agencies can request new official species lists at any time. The Service has 60 days to provide written concurrence or nonconcurrence on the action agency's determination(s) (50 CFR § 402.13(c)(2)), assuming that no essential information is missing from the biological assessment. If information is missing, the Service has 30 days to notify the action agency (U.S. Fish and Wildlife Service and National Marine Fisheries Service (Services) 1998). Consultation information requirements are detailed in 50 CFR § 402.14(c)(1) and include information about the proposed action, the action area, species and designated critical habitat within the action area, and the effects of the proposed action on species and designated critical habitat within the action area (see **3 Information Needs for Plant Consultations**). Once the action agency's biological assessment is accepted by the Service as complete, the Service has 30 days to concur (for "may affect, not likely to adversely affect" determinations) (50 CFR § 402.12(j)) or 90 days to draft a biological opinion (for "may affect, likely to adversely affect" determinations) (50 CFR § 402.14(e)) and another 45 days to finalize a biological opinion in coordination with the action agency (50 CFR § 402.14(e)(3)).

The purpose of this document is to provide recommendations for standardizing and streamlining section 7 consultations for listed plant species and their designated critical habitats. This document is not formal guidance on how to analyze and mitigate potential effects to plant species; rather, it is intended to be a resource for practitioners conducting section 7 consultations involving plants in New Mexico. This document outlines the responsibilities of action agencies under the Act, information needed to analyze effects to plants, and an analysis method and considerations for reaching biologically sound and defensible effects determinations and, as needed, designing effective conservation measures and/or preparing biological evaluations or assessments. Action agency biologists or their designated representatives can apply these recommendations to reach section 7 effects determinations, document their rationales, and solicit technical assistance, concurrence, or a biological opinion from New Mexico Ecological Services Field Office (NMESFO). Although primarily targeted toward action agency staff, other groups participating in the consultation process should find these recommendations helpful for conserving and recovering plant species.

These recommendations are intended to strengthen the quality of information used by our partners to analyze the effects of proposed projects on Federally listed plant species. While this information supports our capacity to conduct jeopardy or adverse modification or destruction of designated critical habitat analyses, it does not identify the level of adverse effects for such determinations. We determine jeopardy/adverse modification on a case-by-case basis, considering project-specific information on baseline habitat conditions, the status of affected populations, effects of the proposed action, aggregated Federal effects, and cumulative effects.

These recommendations were developed based on the best available information and in coordination with agency partners. However, these recommendations are solely intended to represent the recommendations of the Service's NMESFO and should not be assumed to satisfy the expectations of any other entity. Additionally, nothing in this document supersedes applicable laws, regulations, policy, and/or formal orders. While we believe this document to contain timely and accurate information compiled from reliable sources, we make no claims, promises, or guarantees about the accuracy, completeness, or adequacy of the contents of this document, and expressly disclaim liability for errors and omissions in the contents of this document. Conservation is a constantly evolving practice, and we intend to revise this document as new information becomes available and as regulations and policies change. If you notice any errors or omissions or become aware of existing or new relevant information, we encourage you to notify us at nmesfo@fws.gov.

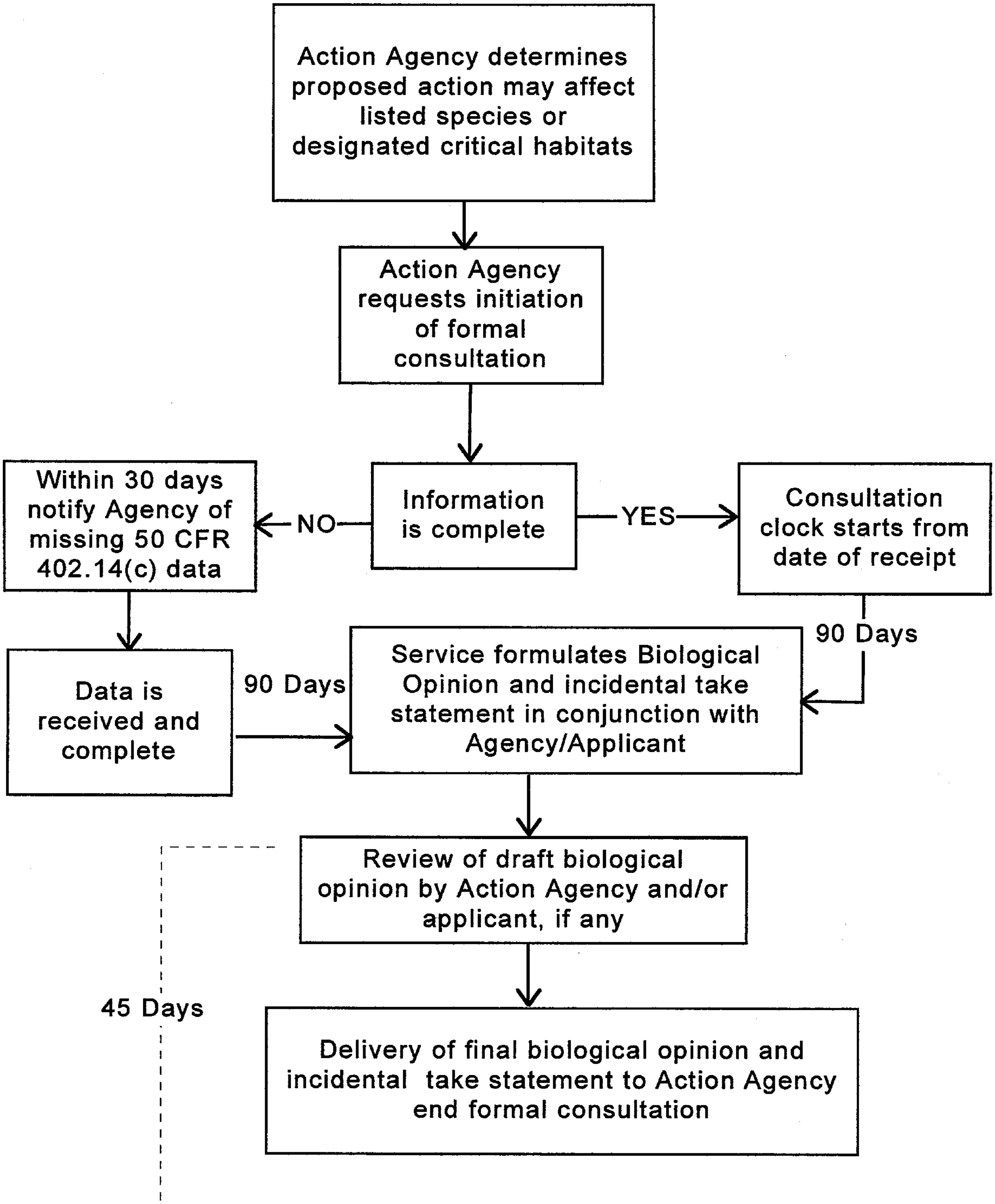


Figure 1.1. Formal consultation process with timelines (Service 1998).

2 Beginning a Section 7 Plant Consultation

Determining if a project has a Federal nexus is the first step in completing a plant consultation. Federal agencies must consult with the Service when any project or action they fund, authorize, or carry out may affect a listed species or designated critical habitat. Federal funding has no minimum amount to be considered a Federal action and includes funds that may be used for contracts or sub-recipient actions. Examples include, but are not limited to, Federal funding for housing, highways or other transportation infrastructure, conservation easements, farm loans or specific practices, conservation grants, disaster mitigation, or community development grants. Federal approval would incorporate issuance of a Federal permit, decision, or any form of approval required for an action. This would include issuance of permit under existing Federal laws or programs. This Federal nexus applies to actions carried out or contracted by Federal agencies and actions involving their lands or other resources under Federal management jurisdiction. State, tribal, and/or private activities may have no Federal nexus if they are carried out using entirely their own funding and with no involvement of Federal lands, resources, or permits. The determination of whether a Federal nexus exists rests with the action agency. However, if the Service can be of assistance with questions about whether a project includes a Federal nexus and would require consultation under the Act, please contact a Service biologist as early in the process as possible to assist in project planning. Figure 2.1 shows decision steps to determine how to proceed with a section 7 plant consultation.

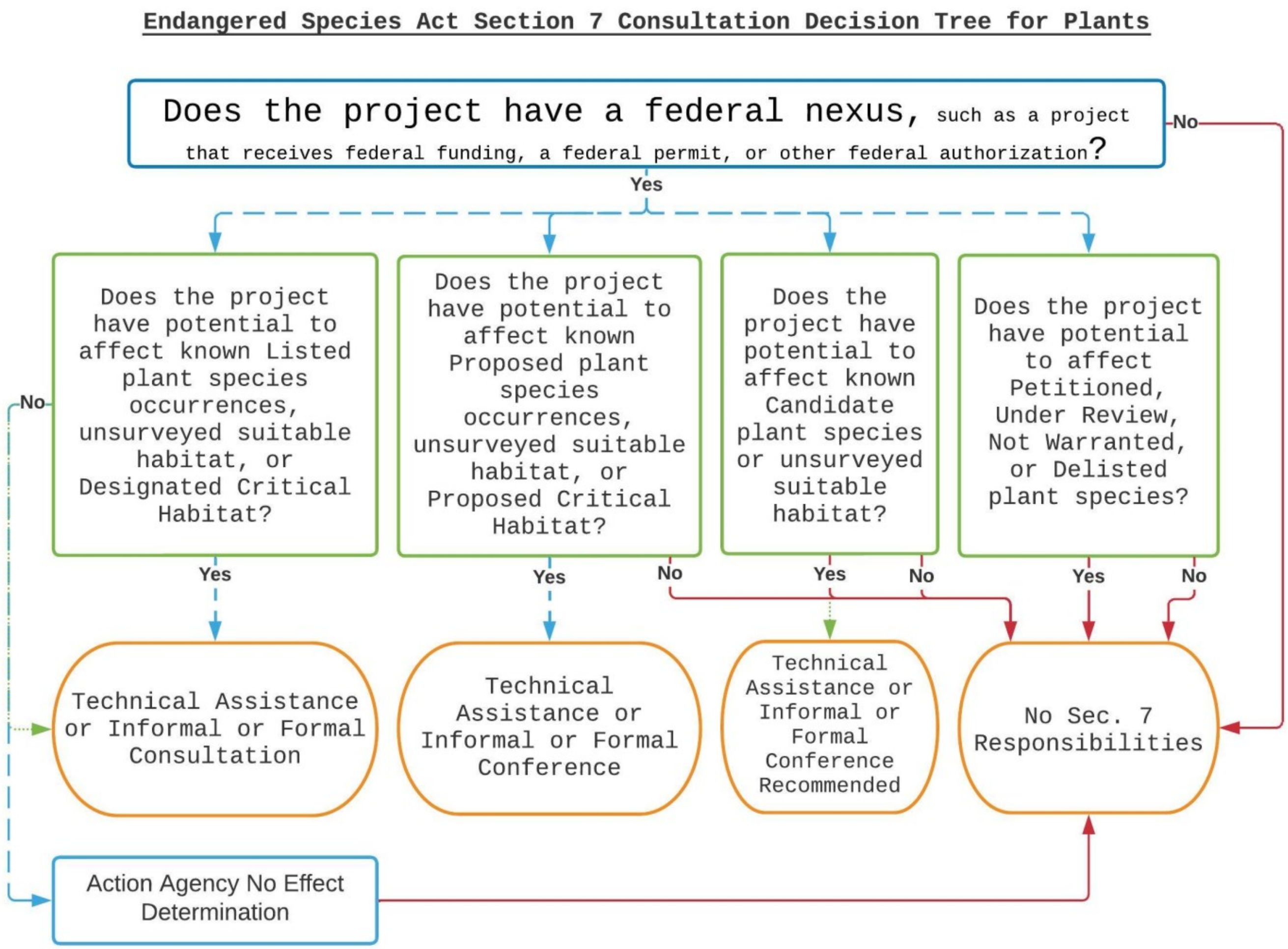


Figure 2.1. Decision tree flowchart for consultation under section 7(a)(2) of the Endangered Species Act. Dashed, blue lines indicate section 7 responsibilities; dotted, green lines indicate additional section 7 options; and solid red lines indicate no further section 7 responsibilities.

3 Information Needs for Plant Consultations

Information needs for a particular project may vary depending on factors such as the complexity of the project, species involved, or the type of action requested from the Service (technical assistance, informal consultation, or formal section 7 consultation). In all cases, the request should provide sufficient information to allow the Service to understand the request and, in the case of consultation (informal or formal), support the determinations made by the requesting agency (see **4 Effects Determinations**). Early coordination with the Service for technical assistance may precede other more official requests and is recommended to address any concerns early in project development. E-mail or telephone inquiries are sufficient for technical assistance. For official informal or formal consultation requests, a formal letter from your agency to the Service is required. Requests from the Service for additional information will typically be made electronically. If existing available biological information is non-existent or incomplete, work with your local Service species lead to determine the best science available. Studies on similar species and/or habitats may provide insights when data is lacking for the species being considered.

The Service shall protect any potentially sensitive data and information to the maximum extent practicable. However, according to the Administrative Procedure Act (5 U.S.C. §§551–559), information you submit for use in our review process will be part of our administrative record and may be subject to release under the Freedom of Information Act (10 CFR § 1004.1). Check with your Service biologist about their preferred file formats and submission methods. A list of species leads by species can be located at https://www.fws.gov/office/new-mexico-ecological-services/species.

3.1 Technical Assistance Information Needs

Regulations guiding the implementation of the Act (found in the Code of Federal Regulations (CFR)) recommend early and frequent coordination to reduce the likelihood of conflicts between listed species or designated critical habitat and proposed projects (50 CFR §402.11). Early coordination on projects with potential to affect listed species or designated critical habitat typically involves technical assistance, such as sharing available information about the presence, abundance, density, or periodic occurrence of listed species and the location of the species' habitat, including any designated critical habitat, in or near the proposed project area. Technical assistance typically also involves establishing avoidance distances and designing plant surveys and conservation recommendations. For early technical assistance, the Service typically needs the following information:

- A map, legal description, or geographic information system (GIS) file that documents the location of the project area and identifies key project features.
- A brief description of the proposed action including project features and any design features and conservation measures (measures proposed to avoid, minimize, or offset adverse effects) that will be implemented.

3.2 Informal Consultation Information Needs

Informal consultation requires an effects analysis and, therefore, detailed evaluation of information about the project, species, and species' designated critical habitat. The Service will need the following information to process a request for informal consultation on a "may affect, not likely to adversely affect" determination (50 CFR §402.14(c)):

- An official list of listed species and/or designated critical habitats that have potential to occur in the action area.
  - This list can be obtained from the Service's Information for Planning and Consultation (IPaC) system: https://ipac.ecosphere.fws.gov/.
- A description of the proposed action, including any conservation measures. The description needs to provide sufficient detail—consistent with the nature and scope of the proposed action—to assess the effects of the action on listed species and designated critical habitat, including:
  - The purpose of the action.
  - The location of the action.
  - The size, duration, and timing of the action.
    - Provide sufficient detail to evaluate the effects of the action on species' critical phenological stages, such as emergence, growth, reproduction, and seed dispersal.
  - The specific components of the action and how they will be carried out.
  - Maps, drawings, blueprints, or similar schematics of the action.
  - Any other available information related to the nature and scope of the proposed action relevant to its effects on listed species or designated critical habitat.
- A map, legal description, or geographic information system (GIS) file of the action area (see ***5.4 Action Area Considerations***): all areas to be directly or indirectly affected by the proposed action, and not merely the immediate area involved in the action (50 CFR § 402.02).
- Information obtained by, or in the possession of, the Federal agency and any applicant on listed species and designated critical habitat in the action area, including available information such as the presence, abundance, density, or periodic occurrence of listed species and the condition and location of the species' habitat, including any designated critical habitat.
  - This should include the results of biological surveys for listed plant species and an evaluation of the physical and biological features (PBFs) essential to the conservation of the species within the action area.
- An analysis of the effects of past and ongoing human and natural factors leading to the current status of the species, its habitat (including designated critical habitat), and its ecosystem within the action area. This information is used to establish the environmental

baseline of an action area and informs effects determinations in addition to jeopardy and/or adverse modification determinations.

- An evaluation of the effects of the action on plant biology and an analysis of any cumulative effects through space and time.
- Any other relevant available information on the effects of the proposed action on listed species or designated critical habitat, including any relevant reports (such as biological survey reports, environmental assessments, and environmental impact statements).
- A summary of any other relevant information provided by the applicant.

3.3 Formal Consultation Information Needs

A formal consultation request should be submitted in the format of a biological assessment. The information in a biological assessment should include all of the information identified for informal consultation as well as the following (50 CFR §402.02; 50 CFR §402.14(g)):

- Appropriate information on the species' life history, its habitat and distribution, and other data on factors necessary to its survival (see **Appendix A: Species Summaries for Federally Listed Plant Species in New Mexico**). This information informs an assessment of a species' or its habitat's vulnerability to effects from proposed actions, leading to jeopardy and/or adverse modification determinations.
- An analysis of the direct and indirect effects of the proposed action on the species and/or designated critical habitat and the consequences of the proposed activities. This information informs an assessment of a species' or its habitat's vulnerability to effects from proposed actions, leading to jeopardy and/or adverse modification determinations.

See the Services' (1998) Endangered Species Consultation Handbook for guidance on composing a biological assessment.

4 Effects Determinations

Under section 7 of the Act, an action agency or its designated representative determines whether their proposed project may affect threatened and endangered (listed) species or designated critical habitat. The following recommendations outline a process for how to make a determination and, if necessary, how to initiate consultation with the NMESFO when an action agency authorizes, funds, permits, or carries out an action that may affect listed species or designated critical habitat. Obtaining official species lists from IPaC (as described in ***3.2 Informal Consultation Information Needs***) allows the action agency to move on to the next phase of section 7(a)(2) review.

To determine if a proposed project may affect listed species or designated critical habitat, the action agency should begin by deconstructing the project into individual actions (e.g., component parts) that would be initiated during the project. Each action is assessed to identify any changes that may occur to the land, water, or air and determine to what extent (e.g., exposure amount, timing, duration, seasonality, etc.) those changes may affect listed species or the physical and biological features of designated critical habitat. Consider all consequences (positive, neutral, negative) of the action, and assess the potential for each life stage of any listed plant species that occurs in the action area to be exposed to the stressors. Ensure that effects of the action on species' critical phenological stages (such as emergence, growth, reproduction, and seed dispersal) are considered for each component part of the project so that effects to listed species are not missed.

Once each project component is assessed to determine potential effects to listed species and designated critical habitat, the action agency should make an effects determination by conducting a thorough analysis of effects to each listed plant species or designated critical habitat that could potentially be affected by the proposed project. The action area to be evaluated when making effects determinations should be based on the consideration of all potential effects to listed species and designated critical habitat from the proposed action and is usually larger than the proposed project area (see ***5.4 Action Area Considerations***). The biologist making the effects determinations should ask whether another activity in question would be reasonably certain to occur, independent of the proposed action under consultation. If the answer is "no," the activity in question would not be reasonably certain to occur "but for" the proposed action, the activity should be analyzed with the effects of the action. For example, "but for" the construction of an access road, a communications tower that is sited within the range of a listed plant species would not be built. Therefore, both the access road and communications tower need to be considered in the effects determination.

The official species list that IPaC generates for a project will generally include species that are not likely to occur in the project area. This is particularly true for endemic plants or other species that have very narrow geographic ranges. Species ranges that IPaC uses to generate species lists are continuously being updated. However, many of them are still represented at a county or other broad geographic level. New Mexico has large counties relative to many other states, and an IPaC list may include species that occur within the same county as a proposed project or action, even if no suitable habitat is present anywhere in the vicinity of the project location submitted to IPaC. Once the IPaC list identifies that a species occurs within the county, the action agency biologist should assess whether the species is known to occur—or if unsurveyed suitable habitat for the species exists—within the project's action area. This should include review of occurrence records, available habitat models, descriptions of any designated critical habitats and their essential physical or biological features, and other information sources that characterize the species' habitat needs, such as recovery plans, species status assessment reports, the New Mexico Rare Plants website, and reports and other published information regarding the species. Links to species' ECOS profiles are included in official IPaC species lists. Critical habitat extent GIS layers can be downloaded individually from ECOS profiles or collectively from ECOS's Critical Habitat Report, and descriptions of any designated critical habitats and their essential physical or biological features are published at 50 CFR §17.96. One of the following effects determinations should be applied to each species identified on your official species list, as well as for each designated critical habitat area identified as overlapping with your project action area. These terms are defined in section 7 regulations at 50 CFR §402.02. A best practice is to document your information sources and rationale as you make each determination.

4.1 No Effect

"No effect" means there will be no consequences (positive or negative) to listed species or designated critical habitat that result from the proposed action, including the consequences of any activities that would not occur but for the proposed action. A "no effect" determination is usually not appropriate if designated critical habitat, listed species, or unsurveyed suitable habitat are present in the action area. Some examples of when a "no effect" determination is appropriate are as follows:

- No listed species or designated critical habitat occur anywhere, or at any time, in the action area (i.e., not just within the immediate project footprint but also outside the immediate area involved in the action).
- A listed species occurs in the action area and may be present at the time of the project, but there are no plausible routes of effects to the species. Designated critical habitat is also in the action area, but there are no plausible routes of effects to designated critical habitat either.

If an action agency determines that the action has "no effect," no section 7 consultation is required. Action agencies should document the "no effect" determination in their files. The action agency is not required to notify the Service or request concurrence for a determination of "no effect."

4.2 May Affect, Not Likely to Adversely Affect

"May affect, not likely to adversely affect" means that all effects to Federally listed species or designated critical habitat from the proposed action would be insignificant, discountable, or completely beneficial. Insignificant effects relate to the size of the impact and include those effects that are not measurable. Discountable effects are effects that are extremely unlikely to occur. Completely beneficial effects include entirely positive effects with no adverse effects to the species.

An example of a "may affect, not likely to adversely affect" determination could be as follows:

- Suitable habitat is within the proposed action area, but the species is not likely to be adversely affected by the project because all associated activities with potential to cause harm or disturbance would avoid critical locations and biological periods and, thereby, prevent the removal, damage, or destruction of the species or its suitable habitat so that effects would be insignificant and discountable.

For designated critical habitat, the action agency determination would be "may affect, not likely to adversely affect," and if the Service concurs, our determination would be "no destruction or adverse modification" if the project will not result in a direct or indirect alteration that appreciably diminishes the value of designated critical habitat for both the survival and recovery of the listed species. Survival is the condition in which a species continues to exist into the future while retaining the potential for recovery, and recovery is the improvement in the status of the listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Act.

4.3 May Affect, Likely to Adversely Affect

"May affect, likely to adversely affect" means that adverse effects may occur to listed species or designated critical habitat from the proposed action and the effect is not insignificant, discountable, or completely beneficial (see ***4.4 Common Flaws in Effects Determinations***). Adverse effects can result from habitat loss, habitat alteration, or impacts to the species life history needs. Before making this determination, we highly recommend contacting the NMESFO first to explore additional actions or modifications to the proposed project that could minimize or avoid adverse effects on listed species or designated critical habitat (see **6 Conservation Measures and Recommendations**).

A determination that a project or activity "may affect, is likely to adversely affect" listed species or designated critical habitat would be appropriate for situations such as the following:

- The species is documented or expected to occur within the action area, and there are likely routes of adverse effects to the species.
- The action area contains designated critical habitat, and it's likely that designated critical habitat could be adversely altered by project features or activities.

If the action may affect designated critical habitat, the Service will determine if the proposed action would result in "destruction or adverse modification" of designated critical habitat.

4.4 Common Flaws in Effects Determinations

Examples of inappropriate arguments or justifications for effects determinations include the following:

- **Project is net positive**. A combination of beneficial and adverse effects is still "likely to adversely affect" even if the net effect (to individuals, populations, and habitat) is neutral or positive.

- **Species can relocate**. This argument is based on an idea that removal of habitat or disturbance of individuals results in a "not likely to adversely affect" or a "no effect" determination because individuals can grow elsewhere either by transplantation or seed restoration. Plants that are forced to grow elsewhere, even in what appears to be suitable habitat, can be stressed during salvage to an extent that precludes survival or successful recruitment.
- **No documented occurrences**. Unless adequate surveys have been conducted in suitable habitat or adequate information sources have been referenced to demonstrate habitat unsuitability, this statement begs the questions "Have you looked?" and "How have you looked?" If suitable habitat is present, and you have not conducted adequate surveys (using accepted protocols), then you must assume the species is present for your analysis.
- **Finding a solution in the future**. Section 7 consultation must be complete before an action is permitted, authorized, or funded. If a Federally listed plant is found at a project site that has not been addressed through a section 7 consultation, work at that site would cease, and the Service would be contacted immediately. Project activities would resume at that location when the Service and action agency have worked to identify suitable avoidance measures and have completed a consultation for the action. Commencing project activities with incomplete consultation could result in costly delays. During project planning, Federal agencies should include adequate time to conduct surveys, gather information, complete analyses, and conduct interagency consultation.

4.5 Changed Circumstances and Reinitiating Consultation

Reinitiating consultation is required, and shall be requested by the Federal action agency, where discretionary Federal involvement or control over the action has been retained or is authorized by law and when any of the following occur (50 CFR § 402.16):

- New information reveals effects of the action that may affect listed species or designated critical habitat in a manner, or to an extent, not previously considered (see ***5.4 Action Area Considerations***).
- The action is modified in a manner that causes effects to listed species or designated critical habitat not previously considered.
- A new species is listed or new critical habitat is designated and may be affected by the action.
- During the implementation of the action, unexpected damage or destruction occurs to listed species or designated critical habitat (see **7 What to Do in the Event of Unintended Damage to Listed Plants or Designated Critical Habitat**).

5 Recommended Analysis Method for Reaching Effects Determinations

This section outlines a standardized analysis methodology and considerations for reaching biologically sound and defensible effects determinations and, as needed, preparing biological assessments that include a comprehensive effects analysis and effective conservation measures. Action agency biologists can apply these methods to reach section 7 effects determinations, document rationale, and solicit concurrence, a biological opinion, and/or a conference opinion from NMESFO during informal or formal consultation, respectively. Effects determinations should discuss the potential effects of the project on listed species and designated critical habitats and address how the conservation measures will ameliorate any adverse effects. Information needed to apply these methods includes plant locations, critical habitat boundaries and descriptions, locations of suitable habitat and/or the locations of the essential physical and biological features of designated critical habitat, proposed project locations, project specifications, and any details relevant to site-specific considerations (see 5.4.4 Site-specific Analysis Considerations).

5.1 Effects Analysis Method Overview

The recommended analysis method for listed plant species is summarized in the following steps and illustrated in Figure 5.1.

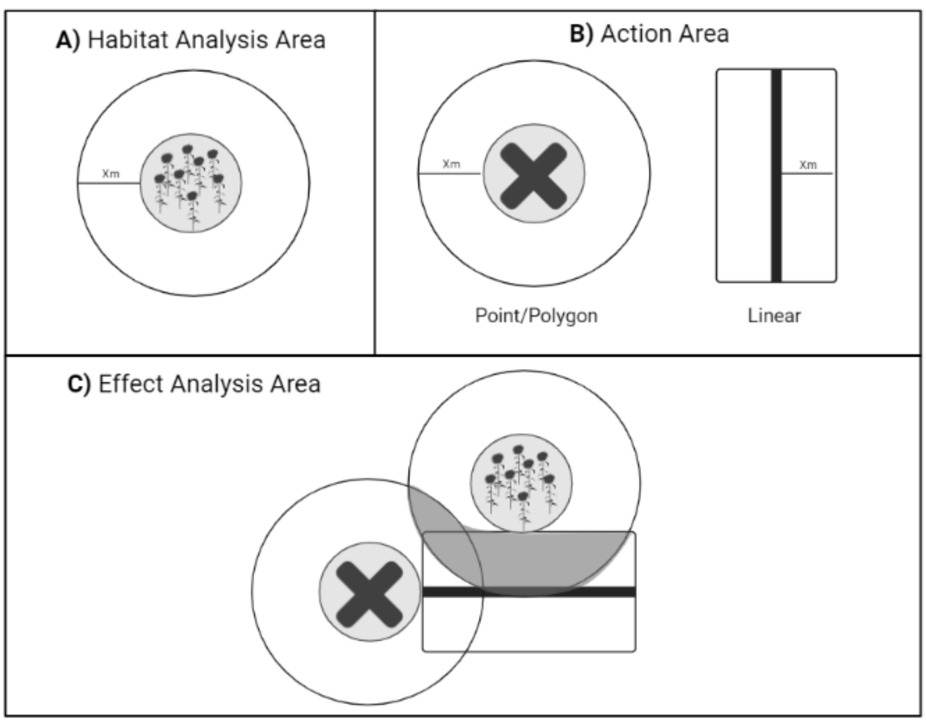


Figure 5.1. Using a habitat analysis area and an action area to define an effects analysis area. A conceptual diagram illustrating A) habitat analysis area (HAA) where "Xm" is the distance used to delineate the HAA, B) action area for both point/polygon (X = action, e.g., disturbance) and linear (e.g., pipeline, road, etc.) features or activities where "Xm" is the radial or perpendicular effects distance, and C) using the HAA and action area to delineate the effects analysis area (EAA), shown as the grey shaded area. Figure created using Biorender.

When analyzing effects to designated critical habitat, substitute critical habitat areas for habitat analysis areas.

1. **Obtain information.** Obtain all preliminary information on the proposed action, project specifications, and plant (or suitable habitat; see step 2, below) habitat and designated critical habitat locations as outlined in section **3 Information Needs for Plant Consultations**.
2. **Delineate the *habitat analysis area* (HAA).** The HAA is defined here as *the spatial area surrounding a species occurrence that includes the physical and ecological conditions that contribute to the species' persistence at that location within which the direct and indirect effects of activities have a potential to affect listed plants.* Because plants do not move and, thus, depend on their surroundings for the conditions and resources necessary to survive, the HAA includes both the direct footprint of a species occurrence and a surrounding area containing physical and ecological factors required by the species for persistence at the given location (see Figure 5.1, A). See Table 5.1 for provisional recommended HAA delineation distances. If presence or absence of listed species can't be determined, all areas of suitable habitat should be considered occupied when delineating habitat analysis areas.
3. **Delineate the *action area*.** The action area is defined by regulation as *all areas to be affected directly or indirectly by the Federal action* and not merely the immediate area involved in the action (50 CFR §402.02). The action area is determined by an evaluation of the reach of the influence (effects distances) of the proposed action on the surrounding environment. Table 5.2 provides recommended *effects distances* for delineating action areas for various activity and feature types. These distances were derived from a literature review (summarized in *5.4 Action Area Considerations*). Effects distances represent a distance extending beyond the direct footprint of an activity or feature (see Figure 5.1, B) within which direct and indirect effects to ecological or physical attributes may occur.
4. **Use the HAA and the action area to identify the *effects analysis area* (EAA).** The EAA constitutes *the physical area within which activities may have an effect on listed species or their designated critical habitat*. The EAA is the focal area to assess how activities or features will affect listed plants or designated critical habitat and develop appropriate conservation measures. The EAA is spatially defined as the overlap of the habitat analysis area and/or critical habitat area and the action area (see Figure 5.1, C).
5. **Analyze effects within the EAA.** Within the EAA, analyze and summarize potential effects from the activities or features associated with the action area and how they will affect (negatively, neutrally, or beneficially) the essential physical and biological features of designated critical habitat and/or the HAA and, thereby, listed species. Account for site-specific considerations (see 5.4.4 Site-specific Analysis Considerations) as needed.
6. **Design conservation measures.** Design conservation measures to ameliorate adverse effects and/or enhance beneficial effects (see **6 Conservation Measures and Recommendations** for conservation measure development recommendations).

7. **Analyze residual effects.** Develop an effects determination (see **4 Effects Determinations**) based on any residual effects from Step 5 that aren't ameliorated by conservation measures adopted from Step 6.

For the purpose of providing standardized methods, provisional distances are provided herein to define both HAAs and action areas for species and activity/feature types, respectively. Applying these provisional distances will result in uniformly shaped areas in concept. However, the practical extent of these areas would deviate from a uniform shape according to topographic position, hydrologic patterns, heterogeneity of physical characteristics like soil or landforms, and an array of other site-specific considerations summarized in 5.4.4 Site-specific Analysis Considerations.

5.2 Species Summaries to Inform Effects Analysis and Habitat Analysis Area Delineation

Effects analysis should be informed by the ecological and biological needs of individuals and populations. Species summaries (see **Appendix A: Species Summaries for Federally Listed Plant Species in New Mexico**) were developed through an extensive literature review and provide a summary of species needs, threats, and recovery and conservation needs for Federally listed plant species in New Mexico. The species summaries provide a framework that can be applied to effects analyses, conservation action design, and effects determinations during the section 7 consultation process. The species summaries may become outdated as additional information becomes available. The Service identifies new, relevant species information in five-year reviews, which can be found within species' ECOS profiles. Additional information relevant to effects analyses, such as recovery criteria, can also be found in species' ECOS profiles. Links to species' ECOS profiles are included in official IPaC species lists.

5.3 Habitat Analysis Areas

An HAA represents the physical area (including and surrounding the direct footprint of a species' occurrence) within which the direct and indirect effects of activities could potentially (adversely or beneficially) affect a listed species (see Figure 5.1, A). Our recommended HAA delineation distances (see Table 5.1) were determined via the systematic scoring process outlined in **Appendix B: Methodology for Delineating Habitat Analysis Areas for Threatened and Endangered Plant Species in New Mexico** (also known as the "HAA Rubric"). This rubric assesses a species' spatial vulnerability based on the sensitivity of its reproductive, demographic, and habitat traits. The characteristics considered in the HAA Rubric were evaluated based on information from the species summaries (see **Appendix A: Species Summaries for Federally Listed Plant Species in New Mexico**) and species experts. *Species with a single known natural occurrence and species that are wetland obligates were not scored using the HAA Rubric* (see Appendix B for information on delimiting HAAs for these species).

Since there is inadequate research by which to designate explicit spatial requirements for any given species or population, we provide provisional HAA distance recommendations here. Provisional HAAs are generalized with the goal of defining a biologically and ecologically meaningful area within which to conduct effects analyses given species reproductive, demographic, and habitat vulnerabilities. As needed, the HAA rubric can be applied to species not currently listed as threatened or endangered under the Act (such as other at-risk plant species), and these species can be placed into provisional HAA categories in order to conduct effects analyses. See the Service's National Listing Workplan for species currently under review for listing under the Act within the next five years.

5.3.1 HAA Distance Delineation Process

Neither HAAs nor their recommended delineation distances represent "avoidance buffers." Rather, they represent areas/distances within which we recommend assessing potential effects to species' ecological and biological needs. **Provisional HAA group delineation distances are based on a minimum distance value of 500 meters (m) (1,640 feet (ft)).** This value represents an estimate of the distance around plants needed to support gene flow, reproductive success, and adaptive capacity within bee-pollinated rare plant populations. This estimate is based on the typical foraging distances of temperate solitary bee species. Social bee foraging distances may be substantially larger, but social bees with large foraging distances are able to cross barriers to reach desirable forage patches, so it's more crucial to protect areas that attract social bees than to protect their entire foraging range. In addition to protecting foraging ranges for the more sensitive solitary bees, the 500 m (1,640 ft) delineation distance is intended to support resilient plant-pollinator communities via large patches of a diversity of good quality, early- to late-season blooming, pollinator forage species (Winder 2012). Therefore, we assume that this distance is also adequate to support gene flow, reproductive success, and adaptive capacity within populations of rare plants dependent on alternate pollinators. Pollinator foraging distance is used as a parameter to set the minimum HAA distance value because *effective pollination is required for reproductive success of outcrossing plant species*. If activities interfere with the ability of pollinators to travel between plant patches, the resulting genetic isolation can lead to reproductive failure (Cunningham 2000), inbreeding depression (Fischer and Matthies 1997; Severns 2003), and eventual extirpation (Lennartsson 2002) of the listed plant species. The 500 m (1,640 ft) minimum HAA distance represents an area within which effects on listed plant species should be analyzed based on increased likelihood of including both nesting habitat for pollinators and adequate forage to attract pollinators from outside of the area.

In addition to pollinator travel distances, other life history, habitat, and distribution characteristics were also factored into HAA groupings (see Appendix B for information on specific traits used for delimiting HAAs). Since these variables are not spatially explicit in all cases and cannot be easily generalized into spatial values, the HAA scoring provides a relative framework of potential spatial sensitivity to effects. Provisional HAA groups provide a recommended distance from a plant occurrence within which the potential for effects should be analyzed. Provisional HAA groups represent relative levels of species spatial vulnerability based on the HAA Rubric scoring outcomes, with distances increasing from HAA group 1 to HAA group 3. For each HAA group representing elevated levels of spatial vulnerability based on the HAA rubric, the provisional HAA delineation distance increases by 100 m (328 ft) compared to the previous HAA group, starting at the 500 m (1,640 ft) distance. Development of species-specific, empirically based HAAs is recommended for more accurate and spatially explicit effects analyses.

5.3.2 Provisional HAA Groups

Provisional HAA groups and their associated HAA delineation distances (see Figure 5.1, A) are presented in Table 5.1.

Table 5.1. Delineation distances and species lists for HAA groups.

Group	HAA Delineation Distance	Species List
Single Known Location	1000 m (3,281 ft)	Holy Ghost ipomopsis (*Ipomopsis sancti-spiritus*) Lee pincushion cactus (*Coryphantha sneedii* var. *leei*) Knowlton's cactus (*Pediocactus knowltonii*)
Wetland Plants	N/A: Use intersecting USGS hydrologic unit (HU) areas at an appropriate scale to capture upstream and downstream influences	Wright's marsh thistle (*Cirsium wrightii*) Sacramento Mountains thistle (*Cirsium vinaceum*) Pecos sunflower (*Helianthus paradoxus*)
Provisional HAA 1	500 m (1,640 ft)	Kuenzler hedgehog cactus (*Echinocereus fendleri* var. *kuenzleri*) Gypsum wild buckwheat (*Eriogonum gypsophilum*) American Hart's-tongue fern (*Asplenium scolopendrium* var. *americanum*)
Provisional HAA 2	600 m (1,969 ft)	Sneed pincushion cactus (*Coryphantha sneedii* var. *sneedii*) Mesa Verde cactus (*Sclerocactus mesae-verdae*) Todsen's pennyroyal (*Hedeoma todsenii*) Zuni fleabane (*Erigeron rhizomatous*)
Provisional HAA 3	700 m (2,297 ft)	Sacramento prickly poppy (*Argemone pinnatisecta*) Mancos milkvetch (*Astragalus humillimus*)

5.4 Action Area Considerations

The action area is defined as all areas to be affected directly or indirectly by the Federal action and not merely the immediate area involved in the action (50 CFR §402.02). Methods for defining the action area and analyzing effects of various activities or features are described in the following sections. These methods focus on: a) general effects associated with a broad range of actions (see section 5.4.1), b) effects and recommended effect distances to delineate the action area for proposed project components (see section 5.4.2), and c) site-specific analysis considerations (see section 5.4.4). Strategic placement of project features, special construction methods, and other mitigation or conservation practices (see **6 Conservation Measures and Recommendations**) can reduce effects distances.

While this section describes the general effects of various actions and provides recommended effects distances for delineating action areas for various activity and feature types, this section is not inclusive of all potential general effects or activities and feature types. Literature reviews of additional general effects (such as artificial lighting) and effects of additional activities (such as those associated with prescribed fire) and feature types (such as stormwater retention basins) may be added to subsequent versions; requests for future additions can be sent to nmesfo@fws.gov.

5.4.1 General Effects of Various Actions

The following are general effects that can be associated with a broad range of project activities and features. These effects should be considered during effects analysis and while developing appropriate conservation measures to avoid and minimize adverse effects to listed plant species. While the focus of this section is on effects to listed plants, suitable habitats, and designated critical habitats, best available science is typically reported in literature as more general effects to plants and ecosystems, as noted below.

5.4.1.1 Fugitive Dust

Fugitive dust is atmospheric particulate matter, especially from airborne mineral soil, that can result from any activity that directly or indirectly facilitates the movement of particulate matter from the surface into the air. Activities that can increase fugitive dust include vegetation clearing, soil disturbance (such as digging, tilling, scraping, and grading), vehicular traffic on unpaved routes, and various mining and quarry operations for processing and transporting extracted minerals. A literature review of papers summarizing the impacts of dust on plants is included in Appendix C, Table C.1. Impacts on plants and ecosystems specific to fugitive dust include:

- direct physiological impacts to individual plants, such as clogging of stomatal openings, leading to reduced photosynthesis and inhibited plant growth (Farmer 1993; Vardaka et al. 1995; Sharifi et al. 1997; Lewis et al. 2017; Kameswaran et al. 2019);
- soil changes such as altered pH, deposition of toxic compounds, and nutrient loss (Li et al. 2007; Ackerman and Finlay 2019; Kameswaran et al. 2019); and

- shifts in vegetation community composition due to altered soil chemistry (Farmer 1993; Auerbach et al. 1997; Myers-Smith et al. 2006; Ackerman and Finlay 2019; Kameswaran et al. 2019).

5.4.1.2 Soil Compaction

Soil compaction is the physical process by which pressure leads to a reduction in void space between soil grains (reduced soil porosity) and a resulting increase in soil bulk density (Nawaz et al. 2013). Soil compaction happens through natural processes and human activities, particularly via vehicles and heavy machinery (Adams et al. 1982), agricultural practices (Singh et al. 2015; Stoessel et al. 2018), and livestock trampling (Castellano and Valone 2007; Allington and Valone 2010). The effects of soil compaction on plants result from the reduced porosity and increased density of compacted soils, which initiate a series of positive feedbacks involving reduced water infiltration and low soil nutrients (Forman and Alexander 1998; Castellano and Valone 2007; Allington and Valone 2010; Singh et al. 2015). Soil compaction and associated feedbacks have been implicated as an important mechanism of desertification with varying degrees of reversibility (Castellano and Valone 2007; Allington and Valone 2010). Impacts on plants and ecosystems specific to soil compaction include:

- reduced plant growth, poor germination, and reduced seedling establishment rates (Forman and Alexander 1998; Castellano and Valone 2007; Allington and Valone 2010; Nawaz et al. 2013; Singh et al. 2015);
- restricted root growth, causing roots to be physically impeded and root physiological processes, such as transpiration and uptake of water and nutrients, to be diminished (Hettiaratchi 1990; Singh et al. 2015);
- diminished density of viable seeds in soil seed banks due to surface disturbance and loss of seed-bearing plants (DeFalco et al. 2009); and
- altered hydrology at local and landscape scales, including reduced infiltration, increased run-off speed, increased channelization, increased sediment transport, and increased erosion severity, with cascading effects on individual plants and vegetation communities (Forman and Alexander 1998; Raiter et al. 2018).

Susceptibility to soil compaction varies with soil texture (soil particle size) and organic matter content (Adams et al. 1982; Díaz-Zorita and Grosso 2000; Nawaz et al. 2013). Soils with finer texture/smaller particle sizes are more susceptible to compaction (Adams et al. 1982; Díaz-Zorita and Grosso 2000), while higher organic content in soils reduces vulnerability to compaction (Díaz-Zorita and Grosso 2000). Organic content additions can be considered when developing mitigation measures to address soil compaction.

5.4.1.3 Land Clearing and Erosion

Land clearing involves the removal of vegetation cover and surface objects (rock, debris) and is often followed by grubbing, grading, or leveling. Land clearing can be associated with a variety of projects, including road construction, well pad construction, and agricultural development. Impacts on plants and ecosystems specific to land clearing include:

- instant mortality of removed vegetation, which may contribute to lasting declines or local extirpations of plant species (Hunter et al. 1987);
- habitat fragmentation and related edge effects (Neldner et al. 2017) (the impacts of habitat fragmentation on plants and supporting habitats are summarized in section 5.4.1.8); and
- increased precipitation run-off speeds and accelerated soil erosion, which can initiate feedback loops that diminish plant cover, soil nutrients, water infiltration, and lead to overall land degradation and desertification (Cowie et al. 2007; Ravi et al. 2010).

Assessing potential effects of erosion will involve examining site-specific considerations (see section 5.4.4) since erosion is higher in areas with steeper slopes, low vegetation cover, and low annual precipitation (Sun et al. 2013).

5.4.1.4 Invasive Species

Activities that involve ground disturbance, alter water courses, or increase traffic from motor vehicles, machinery, humans, or domesticated animals can facilitate invasive species establishment. Many imperiled plant species are threatened, at least in part, by negative impacts from invasive species (Wilcove et al. 1998). Impacts to plants and ecosystems specific to invasive species include:

- altered vegetation structure, composition, and diversity (Walker and Smith 1997);
- altered soil nutrients, microbiota, and chemistry (Walker and Smith 1997);
- altered disturbance regimes, including the frequency, magnitude, severity, and type of disturbances (Walker and Smith 1997); and
- increased competition for resources (e.g., water and light) (Gurevitch and Padilla 2004; Thomson 2005; Dueñas et al. 2018).

5.4.1.5 Water Impoundment, Diversion, and Extraction

Water impoundment, diversion, and extraction can be associated with a variety of project types, including oil and gas operations, mineral extraction, agriculture and livestock production, and residential development. Water diversion involves constructing infrastructure to transfer water from in-stream flows to another watershed or towards a specific end user (e.g., residential, agriculture, industry). Water impoundment involves building a barrier to halt stream flow and create a retention basin for flood control; residential, industrial, and commercial water supply; and/or hydrologic power generation. *Effects of water impoundment and diversion on listed plant species are not reviewed in detail here but should be researched as relevant to proposed actions.*

Groundwater extraction (i.e., pumping subsurface water from aquifers up to the surface) can lower the water table and lead to a disconnect between surface and groundwater systems, such as springs and spring-fed streams and wetlands. Non-wetland plants can also be impacted by lowered groundwater levels. Impacts on plants and ecosystems specific to groundwater extraction include:

- diminished water availability, which can reduce plant species establishment, cover, and/or persistence (Stromberg et al. 1996; Elmore et al. 2006; Hasselquist and Allen 2009); and
- subsidence (gradual sinking of area of land) and fissures (cracking of the earth surface) (Galloway and Burbey 2011).

Depletion and diversion of water resources also impacts wetland ecosystems by increasing salinity (Jolly et al. 2008). Salts that typically enter and exit wetlands through groundwater flow, evaporation changes, sporadic rainfall, and rain/flood cycles become concentrated due to reduced groundwater and surface water flows associated with anthropogenic activities. Impacts on plants and ecosystems specific to increased salinization include:

- decreased plant counts, plant biomass, height, flowering, shoot/leaf number, and size (Jolly et al. 2008);
- a shift in species composition and decreased diversity (Jolly et al. 2008; K. Zhang et al. 2019); and
- changes to soil physical and chemical properties, including a reduction in soil organic matter and soil microbial biomass, which effects nutrient cycling and reduces soil fertility (W. Zhang et al. 2019; K. Zhang et al. 2019).

5.4.1.6 Ambient Air Pollution

Ambient air pollution (such as gas and smoke) travels across administrative boundaries and can result from any activity that directly or indirectly discharges pollutants into the air. Common pollutants include volatile organic matter, heavy metals, nitrogen oxides, and sulfur oxides. These substances can accumulate as poorly soluble contaminants in soils and waterbodies. Plants range from highly sensitive to resilient, and the influence of smoke and gas emissions on sensitive plant species depends on local factors (such as seasonal weather; humidity; predominant wind conditions; the chemical composition, amount, and particle size of pollutants emitted; and the height of emission sources) (Ryabuhina et al. 2019). Impacts on plants and ecosystems specific to ambient air pollution include:

- shifts in vegetation community composition (Ryabuhina et al. 2019);
- an increase in morphological anomalies (Ryabuhina et al. 2019); and
- physiological impacts, contributing to altered growth, development, and appearance (Ryabuhina et al. 2019).

5.4.1.7 Herbicide Treatments

The use of herbicides—a tool to reduce undesirable plant species—can be associated with various activities, including construction and maintenance of transmission lines, well pads, and roads and the treatment of invasive species for conservation or other resource management purposes. Herbicide use can be analyzed as a stand-alone activity or as part of construction or routine maintenance of another activity or feature.

In terrestrial applications, herbicides are most often administered as targeted "spot" treatments via handheld or backpack spray pumps, as broadcast foliar treatments via boom sprayers mounted on vehicles (UTVs, tractors, etc.), or via aerial application from aircraft (for large scale treatments). In aquatic applications, herbicides are most often administered as targeted "spot" treatments via handheld or backpack spray pumps, as broadcast foliar treatments via boom sprayers mounted on boats, as bottom soil treatments via pellet/granule spreaders mounted on boats, as submersed treatments via deep-hose injection equipment mounted on boats, or via aerial application from aircraft (for large scale treatments). Impacts on plants and ecosystems specific to herbicide treatment can include:

- mortality, damage, and biomass reduction (Matarczyk et al. 2002; McManamen et al. 2018);
- suppressed germination, recruitment, and seed production (Erickson et al. 2006; Boutin et al. 2014; Wagner and Nelson 2014; McManamen et al. 2018);
- delayed or reduced flowering (Erickson et al. 2006; Boutin et al. 2014); and
- negative impacts to pollinator species (Davis and Williams 1990).

The relative severity of negative impacts to non-target plants will depend on the type and concentration of chemical used (due to mode of action and soil persistence), methods of application (spot versus broadcast and nozzle types and settings), the growth habit and/or taxonomic affiliations of target and nearby non-target species (due to relative selectivity of chemicals on different growth habits or taxonomic groups), soil characteristics, general climate, the air temperature and humidity at time of application, subsurface hydrological flows, and the timing of application relative to non-target plant phenology. The physical extent of impacts will depend on methods of application (spot versus broadcast and nozzle types and settings), precipitation and surface run-off patterns, and the timing of, and wind speed during, chemical applications. Drift occurs when herbicide travels outside of the intended areas and can occur during herbicide application (primary drift) and after herbicide application (secondary drift) (Bish et al. 2020). Sublimation, a type of secondary drift, occurs when the herbicide enters the atmosphere as a vapor. The extent of drift depends on the mass of particles or droplets released, spray release position (boom height and length), and wind or water speed and direction; active ingredient is not considered to be an influential variable (Hewitt et al. 2002). Herbicide application can also have beneficial effects on non-target plants and can be a tool in promoting diverse native plant communities by reducing competition from invasive species (Mittelhauser et al. 2011; Beck 2014). Refer to "Recommended Protection Measures for Pesticide Applications in Region 2 of the U. S. Fish and Wildlife Service" (hereafter, Pesticide Use Recommendations; White 2007) for regional pesticide recommendations for protecting trust resources. These Pesticide Use Recommendations (White 2007) include avoidance distance recommendations based on pesticide type, species taxonomy, and (for out-crossing species) pollinator size.

5.4.1.8 Habitat Fragmentation

Habitat fragmentation occurs when swaths of habitat for a focal species are divided into smaller, more isolated patches (Lehmkuhl and Ruggiero 1991) and can result from a wide range of activities. Fragmented habitat patches become reproductively isolated from one another, leading to synergistic effects ranging from individual to ecosystem scales. Fragmentation can result from any diffuse or concentrated disturbance that disrupts either the continuity of habitat features required by a species of interest or the ability of that species to maintain genetic connectivity across previously connected metapopulations. Habitat fragmentation is a major threat to rare plant species, which are often at risk of biological consequences from low population sizes and genetically isolated populations. Activities that increase genetic isolation between subpopulations are likely to adversely affect population and species viability.

Assessing habitat fragmentation during effects analysis requires a holistic landscape-level assessment. Consider the following when assessing potential adverse effects from habitat fragmentation:

- species' traits that influence vulnerability to fragmentation; and
- the relative configuration of proposed actions and the extant connectivity of species occurrences.

Contextualizing effects of fragmentation on plants requires considering biological traits that confer relative susceptibility to genetic erosion and other impacts of habitat fragmentation. These traits include:

- reproduction methods (Goodell et al. 1997; Honnay and Jacquemyn 2007);
- pollination syndromes, agents, and degree of specialization (Mustajärvi et al. 2001);
- seed morphology and dispersal mechanisms or agents (Foré et al. 1992; Young et al. 1993; Bacles et al. 2004); and
- life history or growth traits such as longevity, germination characteristics, and adaptations to disturbances driving fragmentation (Menges 1991; Morgan 1999).

The impacts of habitat fragmentation on plants and supporting habitats are summarized in Appendix C, Table C.4. Impacts on plants and ecosystems specific to habitat fragmentation include:

- disrupted pollination in outcrossing plants and related biological consequences such as:
    - inhibited ability of pollinators to travel between populations (Steffan-Dewenter and Tscharntke 1999);
    - reduced pollinator visitation due to insufficient floral displays and nectar resources (Goodell et al. 1997; Honnay et al. 2005);
    - lower probabilities of compatible pollen being carried by pollinators (Kunin 1997; Duncan et al. 2004); and
    - resulting declines in reproductive success (fruit and seed set) in outcrossing plants (Steffan-Dewenter and Tscharntke 1999; Aizen et al. 2009).
- reduced genetic integrity and related biological consequences such as:

  - loss of genetic diversity from genetic drift and inbreeding depression (Aguilar et al. 2019); and
  - accelerated genetic differentiation across isolated populations, resulting in incompatible genotypes across populations (Culley and Grubb 2003).
- reduced habitat integrity and related biological consequences such as:
  - increased edge effects, which are the physical and biological changes that occur at ecotones (the transition between adjoining ecosystems) (Fischer and Lindenmayer 2007); and
  - loss of suitable habitat characteristics needed for dispersal and establishment (Honnay et al. 2002).

5.4.2 Effect Distances for Specific Project Activities and Features

This section outlines rationales for delineating effects distances to establish action areas for a variety of project activities and features. Effects distances are summarized in Table 5.2, and the results of a literature review supporting the values are summarized in Appendix C.

Table 5.2. Effects distances for common project features and activities. Effects distances represent the perpendicular, planar ground distance extending outward from the direct footprint of an action where biologically relevant effects can occur but do not necessarily incorporate the full scope of influences to broader, connected ecosystems such as contiguous aquatic habitats. * = literature review incomplete; recommended values are based on professional opinion, and do not include a narrative summary of available findings from literature.

Feature/Activity Type	Feature/Activity	m (ft)
Roads	Undeveloped/unmaintained vehicle trail	200 (656)
Roads	Developed/mechanically maintained road	500 (1,640)
Trails	Non-motorized recreational trail	100 (328)
Pipelines	Surface/temporary pipeline carrying nonhazardous materials (fresh or treated water)	100 (328)
Pipelines	Below-ground pipeline carrying nonhazardous materials (fresh or treated water)	300 (984)
Pipelines	Surface/temporary pipeline carrying hazardous materials	200 (656)
Pipelines	Below-ground pipeline carrying hazardous materials	400 (1,312)
Transmission Lines/ Utility Corridors	Above-ground transmission line	300 (984)
Transmission Lines/ Utility Corridors	Below-ground transmission line	300 (984)
Oil and Gas Operations: Geophysical Exploration	Land vibroseis (by vehicle)	200 (492)

Feature/Activity Type	Feature/Activity	m (ft)
Oil and Gas Operations: Geophysical Exploration	Land vibroseis (by foot)	50 (164)
Oil and Gas Operations: Wellsite	Wellsite and extraction infrastructure/activities (see below for injection wells)	200 (656)
Oil and Gas Operations: Transportation and Distribution	Compressor station	200 (656)
Oil and Gas Operations: Produced Water Disposal	Disposal pit	500 (1,640)
Oil and Gas Operations: Produced Water Disposal	Surface discharge channel	500 (1,640)
Oil and Gas Operations: Produced Water Disposal	Disposal well (UIC Class II)	200 (656)
Mineral Materials	Processing facility	300 (984)*
Mineral Materials	Transfer facility	300 (984)*
Mineral Materials	Mine	500 (1,640)*
Mineral Materials	Tailings pile	500 (1,640)*
Mineral Materials	Tailings pond	200 (656)*
Mineral Materials	Pit (tailings, mineral materials, and similar)	200 (656)*
Mineral Materials	Core hole pad	100 (328)*
Range	Livestock grazing	Determine site-specifically; depends on stocking rates, allotment boundaries, animal type, etc.
Range	Range improvement (attractant feature, such as a tank, drinker, feeder, etc.)	100 (328)*
Range	Range improvement (non-attractant feature, such as a pipeline, storage tank, etc.)	50 (164)*
Fire	Prescribed fire	Determine site-specifically; depends on a plethora of factors, such as fuel load, burn size, the locations of containment lines and staging areas, etc.
Recreation	Developed or semi-developed campground or other recreational facility	500 (1,640)*
Recreation	Dispersed camping	200 (656)*

Feature/Activity Type	Feature/Activity	m (ft)
Maintenance of Existing Features	Fences	50 (164)*
Maintenance of Existing Features	Herbicide treatment	Apply Service Pesticide Use Recommendations (White 2007)

5.4.2.1 Linear Infrastructure

Linear infrastructure consists of constructed features with a linear configuration (such as roads, non-motorized recreational trails, transmission lines, and pipelines for oil, gas, and water transport) that are typically intended to transport something. Specific components of the linear infrastructure that were considered are described below. When included, additional appurtenant features (such as lighting or crossing structures) may result in greater effects distances.

5.4.2.1.1 Roads

Road construction, use, and maintenance are commonly required for a broad range of activities, including recreation, energy development, fire operations, and livestock or timber operations. For the purpose of effects analysis, roads are distinguished into two categories: undeveloped/unmaintained vehicle trails and developed/mechanically maintained roads. Undeveloped/unmaintained motorized vehicle trails (sometimes referred to as two-tracks) are not graded, surfaced, or otherwise maintained and may include temporary roads built for construction purposes. Developed/mechanically maintained roads are graded and surfaced with various materials, but not necessarily paved; their maintenance may include regular grading, surfacing, and/or vegetation control treatments (chemical or mechanical).

Impacts on plants and ecosystems specific to roads and associated vehicular traffic include:

- increased invasive species establishment (see section 5.4.1.4 for specific biological consequences) (Bradley and Mustard 2006; Brisson et al. 2010);
- increased soil compaction and altered soil properties (see section 5.4.1.2 for specific biological consequences) (Adams et al. 1982; Forman and Alexander 1998; Raiter et al. 2018);
- increased dust generation and pollution (see section 5.4.1.1 for specific biological consequences) (Etyemezian et al. 2004; Lewis et al. 2017; Ackerman and Finlay 2019);
- altered and restricted wildlife movement, impacting pollination and seed dispersal, which can lead to reduced genetic diversity and population viability (Forman and Alexander 1998);
- fragmentation-induced edge effects that extend from the road edge into the then-fragmented ecosystem. Effects from road edges, not mentioned in the general effects section 5.4.1.8 above, and specific to roads and vehicular traffic, include:
    - altered species composition and richness (Angold 1997);

  - altered hydrological patterns (Trombulak and Frissell 2000); and
  - altered soil properties (Auerbach et al. 1997; Ackerman and Finlay 2019).

These effects also apply to other activities and disturbances (such as energy or mineral development and associated infrastructure) that create contrasting habitat characteristics between adjacent environments (Jones and Pejchar 2013).

We reviewed eighteen papers that explicitly quantify the distance from roads within which various effects were detected. Effects distances ranged from 10–1000 m (33–3,281 ft), with an average distance of 400 m (1,312 ft). While effects were documented to extend up to 1,000 m (3,281 ft) from developed roads, effects most frequently occurred within 100 m (328 ft) from the road. Some of these distances are limited by observation distances or transect lengths employed in the various studies (see Appendix C, Table C.2. for a summary of literature and observed effect distances). Based on our review, **we recommend an effects distance of 500 m (1,640 ft) for developed roads.** This distance increases the likelihood that potentially further reaching effects (e.g., invasive species, altered hydrology, fugitive dust) are analyzed. However, specific situations such as those involving permanent or seasonal waterways, construction of permanent stormwater runoff facilities, or culverts larger than those typically associated with road development may require larger buffers than this standard effects distance.

Because two-tracks are not bladed or surfaced, do not involve maintenance activities (such as vegetation management), typically have slower practical driving speeds (resulting in less dust generation), and are less frequently traveled, potential impacts are likely to be less extensive than those of maintained roads; therefore, **we recommend an effects distance of 200 m (656 ft) for unmaintained roads.**

5.4.2.1.2 Non-Motorized Recreational Trails

Non-motorized recreational trails include constructed paths for hiking, biking, and equestrian use. Impacts on plants and ecosystems specific to non-motorized recreational trails include:

- facilitation of invasive species establishment and spread (Tyser and Worley 1992);
- hydrological alterations from increased run-off or channelization associated with trail placement and construction (White et al. 2006);
- trampling of vegetation by humans or domesticated animals (Cole 1986); and
- potentially destructive human activities, such as flower-picking and plant collection, especially if trails are in proximity to listed species occurrences (Ballantyne and Pickering 2015).

We reviewed three papers that explicitly quantified distances from non-motorized trails that effects to plant communities were detected within. Effects distances ranged from 20–100 m (66–328 ft) (see Appendix C, Table C.2. for a summary of literature reviewed). Effects from non-motorized trails reflect a diversity of uses and forms of impacts, which generally increase as use moves from human/foot traffic to stock (Cole 1986). On trails used by pack stock, invading species were found up to the maximum measured distance of 100 m (328 ft) from non-motorized trails, despite richness of alien species decreasing significantly by 25 m (82 ft) (Tyser and Worley 1992). Due to the scarcity of spatially explicit distance values in reviewed literature, and to account for documented impacts such as invasive species and altered hydrology that can extend beyond the trail, **we recommend an effects distance of 100 m (328 ft) for non-motorized recreational trails**.

5.4.2.1.3 Pipelines

Pipelines may be installed below-ground or above-ground to carry liquid or gaseous materials. For effects analysis, pipelines can be split into the following four categories:

- above-ground (non-hazardous materials)
- below-ground (non-hazardous materials)
- above-ground (hazardous materials)
- below-ground (hazardous materials)

Above-ground pipelines are typically temporary transport systems for non-hazardous or hazardous materials. Impacts on plants and ecosystems specific to above-ground pipelines include:

- altered soil characteristics and vegetation community, including mortality, resulting from disturbance associated with maintenance and personnel and vehicles delivering materials (Lathrop and Archbold 1980; Olson and Doherty 2012; Desserud and Naeth 2013; Xiao et al. 2014);
- facilitation of invasive species establishment and spread (Xiao et al. 2014);
- potential for inadvertent releases (leaks) (Balasubramaniyam and Harvey 2014; Baruah et al. 2014; Hawrot-Paw et al. 2015); and
- altered wildlife movement (Jones et al. 2014).

To account for potential impacts from associated disturbances and inadvertent releases, **we recommend an effects distance of 100 m (328 ft) for above-ground pipelines carrying non-hazardous materials**. Potential risks and associated effects distances associated with pipelines that cross streams supporting listed species should be assessed and mitigated based on project- and site-specific considerations.

Construction of below-ground pipelines involves excavating a trench, piling material nearby, and burying the line. Below-ground pipelines involve disturbances to soil structure and plant communities, resulting primarily from excavation, reburial, and maintenance. Impacts on plants and ecosystems specific to below-ground pipelines include:

- mortality and reduced plant cover and productivity (Lathrop and Archbold 1980; Desserud and Naeth 2013);

- altered plant community composition, including invasive species introduction; (Xiao et al. 2014; Richardson et al. 2017); and
- altered soil characteristics, including higher bulk density (indicator of compaction), lower soil moisture holding capacity, and general disruption of soil structure (since topsoil is mixed with deeper soil layers, altering surface soil characteristics that influence plant dynamics) (Soon et al. 2000; DeFalco et al. 2009; Olson and Doherty 2012).

We recommend an effects distance of 300 m (984 ft) for below-ground pipelines carrying non-hazardous materials. This value is based primarily on a study by Xiao et al. (2014) that found most significant impacts to vegetation characteristics occurring within 300 m (984 ft) of the pipeline corridor. Other literature reviewed did not explicitly quantify effects in terms of distances from the pipeline disturbances.

Pipelines (either below- or above-ground) containing hazardous materials (such as toxic or volatile gasses or liquids) can cause more severe and further reaching adverse impacts in the event of a spill or explosion. To account for the added risk of wider-reaching effects from inadvertent releases and explosions associated with above- and below-ground pipelines containing hazardous materials, we recommend adding 100 m (328 ft) to the effects distances for comparable non-hazardous materials transport lines. **We recommend an effects distance of 200 m (656 ft) for above-ground hazardous material pipelines and 400 m (1,312 ft) for below-ground hazardous material pipelines.** Potential risks and associated effects distances associated with hazardous materials should be assessed and mitigated based on project- and site-specific considerations, including possible effects to intersecting aquatic systems.

Techniques that reduce disturbance and promote recovery can lessen negative impacts to plant communities and, in some cases, can result in full recovery of plant and soil characteristics compared to undisturbed areas (Naeth et al. 2020b; Naeth et al. 2020a). Measures to prevent and mitigate adverse effects are outlined in section **6 Conservation Measures and Recommendations**.

5.4.2.1.4 Transmission Lines and Utility Corridors

Electrical power transmission requires construction and maintenance of overhead and/or underground transmission lines to carry electrical power from generating stations to substations and from substations to local users. Transmission line construction and maintenance is similar to road construction and maintenance because it may involve vegetation clearing, construction and use of maintenance roads, dust generation, herbicide use, and linear habitat fragmentation. However, compared to roads, transmission line corridors have vegetative groundcover and experience less frequent vehicular traffic, typically limited to maintenance inspections.

Impacts on plants and ecosystems specific to transmission line construction and maintenance include:

- shifts in species composition (Lathrop and Archbold 1980; Richardson et al. 2017; Çoban et al. 2019), including mortality, reduced perennial grass and forb cover (Lathrop and

Archbold 1980; Beley et al. 1982), and increased invasive or ruderal species abundance after construction (Rubino et al. 2002; Biasotto and Kindel 2018; Çoban et al. 2019);

- persistent changes to soils and hydrological patterns (Biasotto and Kindel 2018); and—
- with the employment of best available management practices, conservation measures, and adequate design features—higher species diversity and potentially beneficial impacts to pollinators or wildlife species that benefit from increased plant diversity (Rubino et al. 2002);

Above-ground transmission lines carry the added risk of potential fire ignition (Mitchell 2009; Biasotto and Kindel 2018). Transmission lines can be an ignition source when high voltage components come into contact with vegetation or other system components due to high wind speeds and/or infrastructure fatigue or damage (Mitchell 2009). Proper maintenance and vegetation management can mitigate fire risk; however, herbicide applications to control vegetation should be reviewed in tandem with transmission line effects analysis (see section 5.4.1.7 for information on herbicide treatments).

Based on the literature review summarized in Appendix C, Table C.2 and assumptions that transmission lines have similar but potentially less far-reaching impacts than maintained roads (due to lower expected vehicle use), **we recommend an effects distance of 300 m (984 ft) for above-ground transmission lines.** Above-ground transmission lines are assigned a higher effects distance than unmaintained roads because potential impacts, such as fire risk and vegetation maintenance, associated with transmission lines may be further reaching.

Similar to non-hazardous below-ground pipelines, below-ground transmission lines involve disturbances associated with excavation, piling, and reburial of transmission cables and associated infrastructure. Therefore, **we recommend an effects distance of 300 m (984 ft) for below-ground transmission lines**.

5.4.2.2 Oil and Gas Operations

Onshore oil and gas operations (O&G) refers to all activities and features associated with the exploration, access, extraction, processing, and transportation of naturally occurring hydrocarbons (e.g., crude oil and natural gas).

5.4.2.2.1 Activity and Feature Type Definitions

This section provides a summary of features and activities associated with O&G to assist with section 7 effects analyses.

- <u>Geophysical Exploration</u>
    - **Seismic Surveys:** methods to detect and identify underground deposit layers using seismic waves and sensors. Seismic waves are generated using explosives or vibroseis (dropping a heavy weight to create vibrations).
        - **Explosives:** detonation of explosives in holes drilled below the surface.

    - **Land Vibroseis**: trucks are used to drop a heavy weight at systematic sampling points, often off-road.

- Well Site Infrastructure
  - **Well Head and Christmas Tree**: a wellhead is the component at the surface of an oil or gas well that provides the structural and pressure seals for the drilling and production equipment. A well head is topped by an apparatus called the "Christmas tree," an assembly of chokes, valves, spools, and fittings to control the flow of fluids.
  - **Artificial Lift Methods and Associated Infrastructure:** equipment for extracting fluids and gas when pressure is not sufficient to naturally force the product to the surface.
    - **Gas Lift**: pressure-dependent valve and tubing system for injecting gas into a well to force underground liquid materials to the surface. The system may include equipment for compression, dehydration, control, and distribution of injection gas.
    - **Pumps**: various types of pumps (e.g., beam pump, jet pump, hydraulic pump) can be added to create pressure to force products to the surface.
  - **Gas Flare**: a gas combustion device, also known as a flare stack, where excess gas is ignited, producing a flame.
  - **Drilling and Production Rig**: a general term for the integrated system that drills wells into the earth's subsurface. The rigs can range in size and be temporary, mobile systems or more permanent. They include well service and workover hoisting units.
  - **Processing and Storage Equipment**
    - **Tank Battery**: storage vessels gathered in one place to hold extracted fluids until they can be delivered to refineries.
    - **Processing Equipment***:* various equipment installed onsite to separate natural gas and liquid phases of the production and remove impurities. This can include vapor recovery units, heater treaters, and compressor stations.
  - **Reserve Pits**: earthen or lined pits used for storage or disposal of drill fluids, mud, and cuttings.
- Well Stimulation
  - **Acid Injection:** pumping of water and hydrochloric acid into a well to dissolve solid minerals and composites that may be blocking a well channel and obstructing the flow of hydrocarbons.
  - **Hydraulic Fracturing:** specially blended, viscosified liquids (typically water, sand, and chemical additives) injected under high pressure to propagate and open

fractures in rock layers, transport proppants to prop the fractures open, and to break up residual gels that impede flow through the fractures.

- **Injection Well:** injection of fluids (often produced water) into a well adjacent to a production well in order to maintain oil reservoir pressure and force oil upward, increasing recovery percentages.

- Transportation and Distribution Infrastructure
  - **Flowlines and Gathering Lines:** small-sized transport lines typically serving one wellhead to carry the fluids or gas to, and in between, individual processing vessels located near or at a well site.
  - **Pipelines:** long pipes used to transport fluids or gas from producers to a user, refiner, purchaser, or other owner.
  - **Compressor Station:** a facility with equipment to stabilize the pressure and flow rate of gases within a pipeline network. Size and number of compressors at a station can vary.
  - **Temporary Surface Usable Water Lines:** pipelines that run above the ground surface and typically remain in place for less than one year. These systems are typically used to transport water with < 10,000 ppm total dissolved solids (TDS) and/or treated produced water. Systems typically involve the use of portable pumps and various types of temporary hoses or piping to transport water from a water source to a temporary holding facility.
- Produced Water Management and Disposal
  - **Disposal Well:** well for injection of wastewater into deep, saline aquifers or depleted oil or gas reservoirs.
  - **Disposal Pits:** lined or unlined earthen pits for the disposal of wastewater associated with oil and gas extraction. In unlined pits, disposal occurs through percolation of fluids into the soil subsurface. In lined pits, disposal occurs through evaporation of fluids and potential onsite burial of concentrated solids that remain in the liner after evaporation.
  - **Surface Discharge:** disposal of wastewater after processing at a centralized waste treatment (CWT) plant where treated water is directly discharged into a channel. While this treated water may be suitable for a given end use, it does not necessarily mean that is potable or safe for use as human drinking water.

5.4.2.2.2 Impacts of Onshore Oil and Gas Operations on Plants and Supporting Habitats

There is a lack of literature about the impacts of many features or activities specific to O&G on plants. A summary of literature reviewed is outlined in Appendix C, Table C.3. When information was lacking, we estimated effects distances based on surrogate, similar features and activities. The following sections outline impacts of specific O&G features and activities as well as rationales for the recommended effects distances in Table 5.2. General impacts on plants and ecosystems from O&G include:

- reduced net primary production, leading to loss of ecosystem services such as forage, biodiversity, and wildlife habitat (Allred et al. 2015; Ochege et al. 2017);
- extensive habitat fragmentation (Jones and Pejchar 2013; Pierre et al. 2018; also see section 5.4.1.8);
- reduced vegetation cover and species richness (Jones et al. 2014);
- increased atmospheric particulate matter (see summary of related impacts in section 5.4.1.1 above);
- increased emission of gases that negatively influence vegetation (Isichei 2014) as well as greenhouse gas emissions, which facilitate accelerated climate change (U.S. Environmental Protection Agency 2012); and
- persistent soil contamination (Otton et al. 2005; Shapiro et al. 2016).

5.4.2.2.2.1 Geophysical Exploration/Seismic Surveys

The largest disturbance associated with geophysical exploration/seismic surveys involving vehicles is cross-country travel with seismic survey equipment. Therefore, many impacts in the sections above that pertain to undeveloped roads apply to this activity. Impacts on plants and ecosystems specific to geophysical exploration/seismic surveys include:

- increased invasive species establishment (see section 5.4.1.4 for specific biological consequences) (Bradley and Mustard 2006; Brisson et al. 2010);
- increased soil compaction and altered soil properties (see section 5.4.1.2 for specific biological consequences) (Adams et al. 1982; Forman and Alexander 1998; Raiter et al. 2018); and
- increased dust generation and pollution (see section 5.4.1.1 for specific biological consequences) (Etyemezian et al. 2004; Lewis et al. 2017; Ackerman and Finlay 2019).

Because cross-country tracks associated with seismic prospecting are typically temporary, there is more potential for vegetation recovery after the surveys have been completed than compared to other types of undeveloped roads that experience consistent traffic (Dawson et al. 2019). However, tracks made by heavy seismic survey vehicles may be perceived as existing two-track roads by the public and traveled for access and recreation. Since seismic surveys involving vehicle travel can leave tracks that may become two-track roads if impacts are not mitigated, **we recommend an effects distance of 200 m (656 ft) for seismic surveys by vehicle.**

Seismic surveys conducted by foot are assumed to share some impacts with other foot travel (invasive species facilitation, trampling, and, if soils are wet, soil compaction). However, impacts are reduced compared to non-motorized trails, which are permanent, require trail construction and maintenance, and concentrate use. **Therefore, we recommend an effects distance of 50 m (164 ft) for seismic surveys conducted by foot.**

5.4.2.2.2.2 Well Site Activities

The construction and maintenance of a well site (see ***5.4.2.2.1 Activity and Feature Type Definitions***) includes many of the features and activities described in the sections above. Impacts on plants and ecosystems specific to construction and maintenance of a well site itself include:

- instant mortality of removed vegetation, which may contribute to lasting declines or local extirpations of plant species (Hunter et al. 1987);
- habitat fragmentation and related edge effects (Neldner et al. 2017) (the impacts of habitat fragmentation on plants and supporting habitats are summarized in section 5.4.1.8);
- increased precipitation run-off speeds and accelerated soil erosion, which can initiate feedback loops that diminish plant cover, soil nutrients, and water infiltration and lead to overall land degradation and desertification (Cowie et al. 2007; Ravi et al. 2010);
- reduced plant growth, poor germination, and reduced seedling establishment rates (Forman and Alexander 1998; Castellano and Valone 2007; Allington and Valone 2010; Nawaz et al. 2013; Singh et al. 2015);
- restricted root growth, causing roots to be physically impeded and root physiological processes, such as transpiration and uptake of water and nutrients, to be diminished (Hettiaratchi 1990; Singh et al. 2015);
- diminished density of viable seeds in soil seed banks due to surface disturbance and loss of seed-bearing plants (DeFalco et al. 2009);
- soil changes, such as altered pH, deposition of toxic compounds, and nutrient loss (Li et al. 2007; Ackerman and Finlay 2019; Kameswaran et al. 2019); and
- increased invasive species establishment (see section 5.4.1.4 for specific biological consequences) (Bradley and Mustard 2006; Brisson et al. 2010).

Because hazardous materials are extracted, stored, and potentially disposed of onsite, the impacts of potential spills should be included in effects analyses of well sites. Impacts of well stimulation should also be considered since this occurs at a well site. Of all the literature reviewed related to O&G impacts to plants and ecosystems (see Appendix C, Table C.3.), only 3 studies quantify the distance from well sites that impacts may reach; these distances ranged from 25–200 m (82–656 ft). The paucity of spatial results in reviewed literature, along with the potential for presence of hazardous materials at well sites, supports application of the high end of the reported impact distances. Therefore, **we recommend an effects distance of 200 m (656 ft) for well sites.** Well sites are also associated with pipelines, powerlines, roads, and other associated infrastructure with effects distances that must be considered separately.

5.4.2.2.2.3 Transportation and Distribution

Transportation and distribution of O&G products is done via access roads and pipelines, both of which are addressed in section **5.4.2.1 Linear Infrastructure**. Impacts on plants and ecosystems specific to transportation and distribution of oil and gas include:

- increased invasive species establishment (see section 5.4.1.4 for specific biological consequences) (Bradley and Mustard 2006; Brisson et al. 2010);
- increased soil compaction and altered soil properties (see section 5.4.1.2 for specific biological consequences) (Adams et al. 1982; Forman and Alexander 1998; Raiter et al. 2018);
- increased dust generation and pollution (see section 5.4.1.1 for specific biological consequences) (Etyemezian et al. 2004; Lewis et al. 2017; Ackerman and Finlay 2019);
- altered and restricted wildlife movement, impacting pollination and seed dispersal, which can lead to reduced genetic diversity and population viability (Forman and Alexander 1998);
- soil changes, such as altered pH, deposition of toxic compounds, and nutrient loss (Li et al. 2007; Ackerman and Finlay 2019; Kameswaran et al. 2019);
- fragmentation-induced edge effects that extend from the road edge into the then-fragmented ecosystem; and
- the potential for inadvertent releases (leaks) (Balasubramaniyam and Harvey 2014; Baruah et al. 2014; Hawrot-Paw et al. 2015).

Compressor stations are situated along natural gas pipeline networks and will encompass impacts related to land clearing, soil compaction, erosion, habitat fragmentation, and herbicide treatments. No literature was found specific to compressor station impacts on vegetation, but effects are assumed to be similar to well sites. Therefore, **we recommend an effects distance of 200 m (656 ft) for compressor stations.**

5.4.2.2.2.4 Produced Water Disposal

Drilling and fracturing wells produces water along with the natural gas. Some of this water is returned fracture fluid and some is natural formation water. In addition to water, these fluids may also contain “naturally occurring salts, radioactive materials, heavy metals, and other [toxic] compounds from the formation” drilled (Pichtel 2016). Produced water is classified by the U.S. Environmental Protection Agency (EPA) as Technologically Enhanced Naturally Occurring Radioactive Material, or TENORM (U.S. Environmental Protection Agency 2015b, unpaginated). Hydraulic fracturing fluids may contain known toxic substances or unknown proprietary substances (Pichtel 2016). Produced water can be disposed of via disposal pits or underground injection control (UIC) Class II wastewater disposal wells (U.S. Environmental Protection Agency 2015a, unpaginated). Produced water that is not reused or disposed of via injection is typically put in shallow pits where water may evaporate and materials degrade.

Produced water can be stored in permanent pits or in temporary well fluid management pits. Their use in New Mexico is governed by the Oil Conservation Commission.

Impacts on plants and ecosystems specific to produced water disposal include:

- the introduction of excess salinity and sodicity, which can cause clays to deflocculate, thereby lowering the permeability of soil to air and water (Pichtel 2016);
- excess soluble salts, which can cause plants to desiccate and die; and
- the inadvertent or intentional release of wastewater, which may result in areas with minimal vegetation cover ("salt scars") and increased salinity permeating and persisting in the soil subsurface and groundwater where it can influence plant-soil interactions (Otton et al. 2005).

To account for direct ground disturbance, along with potential for contamination via leakage or spills (see section 6.1.2.1 for containment measures to minimize contamination risks), **we recommend an effects distance of 500 m (1,640 ft) for disposal pits and surface discharge methods of treated wastewater.** The distance for surface discharge is measured as the distance from the perimeter from any path of travel of the discharged material. Wastewater disposal wells that are used to inject material into deep, isolated rock formations present less of a potential hazard than disposal pits and surface discharge since they are less likely to result in contamination. Therefore, **we recommend an effects distance of 200 m (656 ft) for wastewater disposal wells.** This may increase in unique situations and may fluctuate based on resource sensitivity (waterways, drainages, wetlands, etc.) on a site-specific basis.

5.4.2.2.2.5 <u>Hazardous Materials Release (Hydrocarbons)</u>

Common sources of hazardous materials releases include extraction, storage, transportation, alteration, refinement, use, and disposal of hazardous materials. The adverse effects of hazardous materials increase in severity with increasing levels of contamination, which depends on spill volume, content, and extent (Baruah et al. 2014). In some cases, the release of hazardous materials can result in an explosion. Impacts on plants and ecosystems specific to hazardous material releases include:

- atmospheric pollution and soil contamination, which can contribute to shifts in vegetation community composition and physiological impacts, such as reduced photosynthesis, altered growth, development, and appearance, and an increase in morphological anomalies (Balasubramaniyam and Harvey 2014; Baruah et al. 2014; Hawrot-Paw et al. 2015; Ryabuhina et al. 2019); and
- disturbance associated with emergency response/intervention and post-release remediation.

The potential for spills and contamination should be considered in effects analyses and when delineating effects distances because releases and associated contamination can create immediate and lasting adverse effects on listed plant species and significantly influence species viability.

Mitigation measures to prevent or contain potential spills are summarized in section **6 Conservation Measures and Recommendations**.

5.4.3 Activities Requiring Site-specific Analysis

Our literature review yielded an incomplete analysis of effects distances for all activities. Recommendations to assist in developing site-specific effects distances for other common land use activities are described below.

5.4.3.1 Renewable Energy

Onshore renewable energy development and operations involve application of diverse technologies that share some impacts with oil and gas operations and other land use effects discussed in this section. However, effects distances based on O&G activities and features may not be comparable for effects from renewable energy project activities and features. For example, wind turbines can change wind patterns and alter soil moisture and nutrient distribution at greater distances than well pad features (Miller and Keith 2018), and land clearing for utility-scale solar sites is often substantially more extensive than for O&G well sites (Ong et al. 2013; Pierre et al. 2018; Bolinger and Bolinger 2022). Therefore, we recommend that effects distances for wind, solar, and other forms of renewable energy be determined on a site-specific basis by deconstructing project activities and features into their component parts. Renewable energy facilities may also involve above-ground and below-ground transmission lines, developed and undeveloped roads, fences to control access, and herbicide application for vegetation management below or around solar panels. Effects distances listed in table 5.2 may be applicable for these types of project activities and features.

5.4.3.2 Diffuse Activities (Grazing, Fire, etc.)

Diffuse activities do not occur in a discrete or uniform spatial area and thus cannot be prescribed consistent distances for defining the action area. The action area would instead depend on the spatial extent of the activity (e.g., allotment areas to be grazed by livestock, areas to be burned).

5.4.4 Site-specific Analysis Considerations

This section outlines provisions of the Act that involve site-specific analyses, as well as recommendations for additional site-specific considerations that may be necessary to inform effects analyses and develop effects determinations.

- Environmental Baseline
    - When considering the effects of the action on Federally listed species, the Service is required to take into consideration the environmental baseline. Regulations implementing the Act (50 CFR 402.02) define the environmental baseline as the past and present impacts of all Federal, State, or private actions in the action area. Also included in the environmental baseline are the anticipated impacts of all proposed Federal actions in the action area that have undergone formal or early

section 7 consultation and the impacts of State and private actions that are contemporaneous with the consultation in progress.

- Cumulative Effects
    - Assess effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation (50 CFR §402.02). This definition applies only to section 7 analyses and should not be confused with the broader use of this term in the National Environmental Policy Act (NEPA) or other environmental laws.
- Unoccupied Critical/Suitable Habitat
    - For species with designated critical habitat, unoccupied designated critical habitat consists of suitable habitat areas within which the species has been locally extirpated or areas where the species may have never occurred but where essential features or processes exist for maintaining the species' habitat (Services 1998). Analyzing and mitigating potential adverse effects to these areas is essential for species protection and recovery. Similar logic applies to suitable habitat for species without designated critical habitat. To assess unoccupied suitable and/or designated critical habitat at a project site, use the designated critical habitat descriptions in 50 CFR § 17.96(a), species summaries (see **Appendix A: Species Summaries for Federally Listed Plant Species in New Mexico**), and site assessments to delineate the spatial extent of features, processes, and species known to be required by, or associated with, the species under consideration.
- Status of the Species within the Action Area
    - Summarize the number of individuals, spatial extent, and location of species occurrences to assess status of the species within the action area. See the Service's **Standards for Conducting and Reporting Consultation Surveys for Federally Listed, Proposed, and Candidate Plants in New Mexico** for our office's minimum standards for botanical surveys for target plant species. Discuss the condition of the species and (if applicable) designated critical habitat in the action area, the factors responsible for that condition, and the relationship of the action area to the survival and recovery of the species.
- Extant Connectivity and Fragmentation Potential
    - Analyze how activities will impact connectivity and implications for genetic diversity among and within subpopulations based on pollination biology and spatial configuration of plant occurrences. See **5.4.1.8 Habitat Fragmentation** for a discussion of habitat fragmentation considerations.
- Relative Topographic Position of the EAA, Designated Critical Habitat, and Species HAAs
    - Consider the placement of project activities and features relative to any designated critical habitat and the species' HAA. Analyze how activities will impact air flow, hydrology, soil movement, and geomorphic features and how

such impacts could affect the plants. If applicable, also consider how hazardous substance releases would disperse and drift or how uncontained fire would spread.

- Timing and Duration
    - Assess how the timing and duration of project activities interact with species' needs and life cycles.
- Geology and Substrate
    - Assess the site soil chemical and physical properties to understand relative susceptibility to erosion, compaction, and chemical alteration.
- Prevailing Wind Direction
    - Identify the prevailing wind directions to assess how dust, herbicide, or airborne pollutants will disperse.

In addition to site-specific characteristics, species and populations vary in their responses to different types of activities and features. Such variations may result from relative exposure to, vulnerability to, sensitivity to, tolerance of, or adaptations to different influences. Species- and population-specific responses to potential effects from proposed project activities and features should be considered in effects analyses.

6 Conservation Measures and Recommendations

This section outlines considerations for developing biologically sound conservation measures and recommendations or reasonable and prudent alternatives to a proposed action. Conservation measures are actions that will be taken to benefit, or promote the recovery of, listed species and are included by the Federal agency as an integral part of the proposed action. These actions, once included in the BA and BO, are non-discretionary and will be taken by the Federal agency or applicant to avoid, minimize, or compensate for adverse project effects on listed species. Conservation recommendations are the Service's non-binding suggestions resulting from formal or informal consultation. Because there is no incidental "take" for plants under the Endangered Species Act, terms and conditions on incidental take permits are not issued for plants; instead, the Service will make "conservation recommendations." Conservation recommendations are discretionary and:

- identify discretionary measures a Federal agency can take to avoid or minimize the adverse effects of a proposed action on listed species or designated critical habitat;
- identify studies, monitoring, or research to develop new information on listed species, or designated critical habitat; and
- include suggestions on how an action agency can assist species conservation as part of their action and in furtherance of their authorities under section 7(a)(1) of the Act.

In cases where an action is likely to jeopardize the listed species or is likely to adversely modify its designated critical habitat, the Service may provide reasonable and prudent alternatives or measures in the biological opinion. In accordance with regulations, "reasonable and prudent" alternatives are those actions that could be implemented in a manner consistent with the intended purpose of the agency action, that are feasible and within the scope of action agency's authority, and that reduce the likelihood of jeopardizing the continued existence of the listed species or of destroying or adversely modifying designated critical habitat.

It may be useful to deconstruct activities and then design corresponding conservation measures for each deconstructed activity. To identify potential effects by deconstructed activities, please reference section 5.4 of this document. For species with published effect pathways and conservation measures, you may utilize the Effects Pathway Manager within the Consultation Package Builder in IPaC to develop conservation measures associated with various activities. However, there are currently no published effect pathways and conservation measures for listed plants that occur in New Mexico in the Effects Pathway Manager.

The Council on Environmental Quality (CEQ) defines mitigation in 40 CFR 1508.1 as "measures that avoid, minimize, or compensate for effects caused by a proposed action or alternatives as described in an environmental document or record of decision and that have a nexus to those effects." Mitigation is further defined by CEQ as including the following:

- avoiding impacts by not taking a certain action or parts of an action,
- minimizing impacts by limiting the degree or magnitude of the action and its implementation,
- rectifying impacts by repairing, rehabilitating, or restoring the affected environment,
- reducing or eliminating impacts over time by preservation and maintenance operations during the life of the action, and
- compensating for impacts by replacing or providing substitute resources or environments.

These measures are hierarchical in nature, with avoidance being the preferred approach in all cases, followed by minimization and then compensatory mitigation. The following sections describe and provide examples of conservation measures in each of these categories. For more information on compensatory mitigation, please refer to the Service's Mitigation Policy (2023) and Endangered Species Act Compensatory Mitigation Policy (2023) as well as any future policy published by the Service.

6.1 General Conservation Measures

General conservation measures are global in nature and may be applied to a variety of action activities. Section 6.2 details conservation measures that have been used previously to mitigate specific effects.

6.1.1 Avoidance Measures

Avoidance measures focus on altering the location (spatial avoidance), timing (temporal avoidance), or methods (other avoidance) of an activity to avoid direct and indirect impacts. Avoidance should be considered the highest priority strategy when developing conservation measures.

6.1.1.1 Spatial Avoidance

The following conservation actions can be included as spatial avoidance measures:

- Establish buffer zones (avoidance areas) around known occurrences of listed species and/or their habitats, such as a buffer zone indicating where vehicle use, herbicide application, or mulch application is prohibited.
- Provide a biological monitor to help guide project participants to avoid occurrences of listed species and/or their habitats.
- Install physical structures, such as barriers and fences, that restrict human and/or animal access to listed species and/or their habitats (Service 1985b; Service 1997; Service 2000; Service 2005a; Service 2007a; Service 2009; Service 2018; Service 2020a; Service 2020b).
- Bore under, rather than dig through, occurrences of listed species and/or their habitats (if boring, be sure to also address risks from future surface travel along the corridor).

    - Borehole depth is site- and species-specific. Ensure that the depth is sufficient to avoid direct and indirect effects to both plant roots and the local water table, including any potential effects from subsidence, thermal radiation, or inadvertent releases.

- Ensure that avoidance areas are clearly marked in contract plans and maps.
- Avoid listed species and/or their habitats or relocate the action (Service 1985a; Service 1985b; Service 2000; Bureau of Land Management 2001; Service 2002; Service 2005b; Service 2007a; Service 2009; Service 2012; Service 2020a; Service 2020b).

6.1.1.2 Temporal Avoidance

The following conservation actions can be included as temporal avoidance measures:

- Avoid working during sensitive seasons; avoid the growing season to avoid impacts to plants (e.g., conduct prescribed burns or grazing in an occupied area while the plants are dormant), and avoid reproductive periods to avoid impacts to pollinators and reproductive structures, such as from dust or pesticides (Service 2018; Service 2020a).
    - Active, reproductive, and dormant periods vary by species and in response to variable environmental conditions. Calibrate on species' phenology before conducting potentially harmful activities.
- Avoid working when soils are moist to reduce the risk of soil compaction and erosion, and avoid working when wind speeds are high to reduce fugitive dust and primary or secondary drift of toxic substances.

6.1.1.3 Avoidance – Other

In addition to spatial and temporal avoidance measures, the following conservation actions can be included as avoidance measures:

- Educate workers about the species and its habitat to prevent unintended human destruction (e.g., accidental crushing of plants) (Service 1985a; Service 1985b; Service 2007a; Service 2009; Service 2012; Service 2020a).
- Incorporate a stop work clause to protect any new occurrences of listed plants that are discovered during project activities (Service 2002; Service 2020a).

6.1.2 <u>Minimization Measures</u>

Minimization measures aim to limit the degree or magnitude of reasonably plausible adverse effects. The following conservation actions can be included as minimization measures.

6.1.2.1 Containment

Containment measures minimize changes to the physical, biological, and chemical environment (i.e., dust, chemical spills, erosion, invasive species, and sedimentation). The following conservation actions can be included as containment measures:

- Hazardous chemical containment
    - Substitute equally effective, less toxic products.
    - Spot treat with, and hand-apply, hazardous chemicals to reduce drift and avoid effects to non-target species or areas.
    - Create a spill prevention, leak detection, and inadvertent release response plan.
    - Check equipment regularly for wear, leaks, and spills.
    - Avoid chemical handling or application during adverse weather conditions.
    - Avoid storing, transporting, or handling hazardous materials near water bodies, water courses, or in flood plains.
    - Use drift reduction techniques or additives to minimize drift and surface runoff.
    - Use drip pans and absorbent pads in leak prone areas, such as below valves.
    - Use secondary containment when storing or transporting hazardous materials containers; install dikes or berms around larger containers, such as drums and tanks. The Gold Book: Surface Operating Standards and Guidelines for Oil and Gas Exploration and Development (U.S. Department of the Interior and U.S. Department of Agriculture 2007) includes specifications for containment structures.
- Erosion and Dust
    - Minimize temporary and long-term exposed ground, such as by minimizing project feature footprints, mulching, hydro-seeding, applying bonded fiber matrix or jute mesh, paving, or replanting.
    - Install structures (such as check dams, coir logs, or silt fences) to reduce runoff velocity and capture fugitive sediment.
    - Conduct dust-generating activities during low wind and/or peak precipitation seasons.
    - Increase the density of particles by watering with potable water or applying non-toxic binding agents.
    - Install windbreaks to slow and/or redirect wind.
    - Minimize traffic.
    - Adopt and enforce speed limits, install speed limit signs.
    - Use tires with low-impact tread.
- Heavy equipment and motorized vehicles.
    - Establish designated parking areas and vehicle travel routes.
    - Avoid cleaning, refueling, and staging heavy equipment and motorized vehicles near water bodies, water courses, or in flood plains.

  - Install physical structures, such as barriers and fences, that restrict heavy equipment and vehicle access to listed species and/or their habitats.
  - Provide a biological monitor to help guide project participants to avoid occurrences of listed species and/or their habitats.
- Grazing and/or trampling animals
  - Install physical structures, such as barriers and fences, that restrict animal access to listed species and/or their habitats.
- Fire
  - Conduct prescribed fires or high fire risk activities during low wind and/or peak precipitation seasons.
  - Use human made or natural firebreaks and/or ecologically appropriate fire retardants to reduce the risk of fire escape and limit fire spread (fire retardants may have adverse effects on listed plant species, so use them appropriately).
  - Provide a fire watch and water source for activities with high fire risk, such as camping or welding.
  - Install physical structures, such as fire shelters, to avoid sparks or fire reaching plants.
- Exotic species
  - Create a weed prevention, detection, and treatment plan.
  - Control exotic plants in the action area prior to conducting activities that could spread or transport them.
  - Set up weed washing systems or designated weed washing areas, and clean equipment before entry into the action area and after leaving areas where invasive species are known to occur.
  - Establish designated parking areas and vehicle travel routes.
  - Use certified weed-free native seeds, plants, and mulches for erosion abatement and restoration/reclamation.
  - Monitor and treat the action area for exotic plants seasonally for at least three years post-disturbance.

6.1.2.2 Methodological Minimization

Minimization measures can include adjustments to methods involved in construction and/or conducting activities to minimize foreseeable impacts. Methodological minimization eliminates unnecessary features or activities and makes use of the least intrusive tools, equipment, devices, forces, or practices that will achieve the project objectives. Examples of methodological minimization measures are infinite. These are just a few examples to spark your imagination:

- Use shoes and/or tires with low-impact tread to minimize trampling, ground disturbance, and erosion.
- When appropriate, minimize ground disturbance by using digital and/or aerial equipment to monitor, inspect, and/or maintain project features.
- Avoid blading before fence installation or pipeline burial.
- Mow when plants are dormant.

6.1.2.3 On-Site Third-Party Biological Monitors

For projects where plants will be impacted or where plants are within or adjacent to the project area, a third-party biological monitor is recommended (Service 2007a; Service 2012; Service 2020b). Duties of this third-party monitor may include the following:

- Monitor avoidance of plants and habitat during all construction-related activities, including the initial delineation of construction exclusion areas (e.g., fenced and flagged areas).
- Ensure plants are not damaged and that all applicable conservation measures in the biological opinion/concurrence letter/biological assessment are implemented during project construction.

6.1.3 Rectification and Reduction Measures and Compensatory Mitigation

While avoidance and minimization measures occur before and during project implementation, rectification and reduction measures typically occur after project implementation. Compensatory mitigation measures may occur during or after project implementation, but we recommend that they occur prior to project implementation (Service 2023b; Service 2023a). Rectification measures attempt to repair, rehabilitate, or restore the affected environment. Rectification involves restoring habitat availability, suitability, and connectivity. Reduction measures attempt to reduce or eliminate impacts over time through preservation and ongoing maintenance operations. Reduction involves active management to improve affected resources within an action area, such as augmenting populations, monitoring for, and controlling, exotic species, and conducting prescribed fires, floods, etc. needed to maintain habitat quality. Once all appropriate and practicable measures are taken to avoid, minimize, rectify, or reduce effects, compensation or offsets for the remaining unavoidable impacts may be considered to achieve no net loss (undiminished species status relative to pre-project conditions). Compensatory mitigation conserves species and their habitats by replacing or providing substitute resources or environments through restoration, establishment, or preservation of resources and their values, services, and functions. Compensatory mitigation typically involves enhancing, creating, and/or safeguarding populations and habitats in alternate locations identified in conservation plans.

6.1.3.1 Restoration and Reclamation

Site stability and ecosystem functions and services should be expediently restored/reclaimed to pre-disturbance conditions (including topography, land productivity, ecological diversity, and native vegetation) following the action to reduce long term impacts to listed plant species in the vicinity of the action area. The following conservation actions can be included as rectification or reduction measures:

- Re-create or restore topography, natural barriers, and natural drainage patterns that have been disturbed.
- Conserve removed topsoil, preserve the seed bank within the removed topsoil, and reapply/respread salvaged topsoil following construction.
- Apply soil amendments to restore soil quality (i.e., increase biotic nutrients, remediate compaction, and promote soil development), as appropriate.
- Loosen compacted soil using deep tillage equipment, hand tools, or other methods to rectify compaction, as appropriate.
- Roughen the soil surface using hand tools or heavy machinery to promote establishment of a biocrust and vegetative cover and to reduce erosion.
- Seed with ecotypic native species and apply certified weed free mulch, as appropriate.
- Monitor for, and control, exotic plant species pre- and post-disturbance.
    - Plan for ongoing monitoring, follow-up visits, and repeated treatments. If exotic plant treatments occur within or near listed plant populations, also plan to periodically monitor for unanticipated effects to listed plants.
    - Remove or treat exotic species in accordance with the 2018 Invasive Plant Control Project Final Environmental Impact Statement for the Carson and Santa Fe National Forests (U.S. Forest Service 2018) and the Environmental Assessment for Integrated Pest Management of Noxious/Invasive Plants for the Cibola National Forest (U.S. Forest Service 2010).
    - Prior to treating exotic species, survey the action area for listed species. If any listed plants are encountered, establish avoidance buffers for them.
    - Use manual, mechanical, or cultural control methods when feasible, but avoid adverse effects to listed species and their habitats.
        - Manually control exotic plants by pulling, bagging, and disposing of whole plants and/or their reproductive structures.
        - Mechanically control exotic plants by tilling, mowing, cutting/felling, and/or masticating them.
        - Culturally control exotic plants by mulching, burning, or grazing them.
        - Train applicators to identify rare plants and their habitats and avoid manual, mechanical, and cultural control within a certain distance of sensitive plants and their habitats.
        - If grazing, develop a grazing plan to address effectiveness and ensure that impacts to non-target species are not occurring.
        - Apply relevant containment minimization measures for exotic species.

- Avoid listed plant species and their habitats during herbicide application.
    - Train applicators to identify rare plants and avoid application within a certain distance of listed plants.
    - Adhere to herbicide best management practices, including ensuring that applicators are certified and follow herbicide label requirements.
    - Select the most effective herbicide with the lowest effective rate that requires the least number of re-applications.
    - If spraying in water, or where the water table is within 6 feet of the soil surface, only use herbicides labeled and approved for aquatic use. Follow all label directions. Avoid broadcast and aerial application of herbicides; use spot treatments instead.
    - Avoid the use of herbicides with potential to adversely affect pollinators.
        - See White (2007) for more information about the ecotoxicity of pesticide active ingredients and various formulations on bees, other arthropods, avian species, and plants.
    - Consider weather conditions, and avoid application when winds exceed 10 miles per hour or when rainfall is imminent.
- Avoid biological controls, such as insects, that may also control the growth and reproduction of listed species.
    - Use of biological control agents would likely require further section 7 consultation.
    - Biological control agents and their effects on listed species should be carefully monitored.

6.1.3.2 Translocations

When destruction of plants is unavoidable, transplantation of the plants outside of the project area is typically proposed (Service 1985a; Service 2000; Service 2001; Service 2007a; Service 2009; Service 2020a). Emergency salvage via transplanting (relocating individuals threatened with death within a crisis-responsive timeframe) has historically been considered a form of compensatory mitigation referred to as mitigation translocation (Bradley et al. 2022). However, emergency transplanting success rates are low, likely because successful translocations require a significantly greater investment in time, expertise, and resources that those currently invested in emergency salvage actions (Bradley et al. 2022). Most efforts to establish new populations of rare plants are inadequately maintained and/or monitored and fail or show only short-term success (Fahselt 1988; Fiedler 1991; Godefroid et al. 2011; Bradley et al. 2022). Therefore, we do not consider translocation to be a form of compensatory mitigation (see **6.1.3.4 Compensatory Mitigation**). Further, translocations should not proceed without assurance of funding for all essential activities over an adequate period of time (IUCN-SSC 2013).

Since survival of transplanted individuals is low and establishment of self-sustaining introduced populations is unlikely to be within a proposed project's timeline or budget, we recommend collecting/conserving and locally reintroducing (before/during and after implementation of project activities, respectively) seed from individuals at-risk of destruction as a rectification and reduction measure. This effort is more likely to effectively and efficiently reduce and eliminate adverse effects to genetic diversity within a population from a loss of plants. Seed collection and seed reintroduction timing can be very specific, so plan ahead to ensure success.

If emergency salvage (transplant) or introduction efforts are undertaken:

- Follow the Center for Plant Conservation's best practice guidelines for the reintroduction of rare plants (Maschinski and Albrecht 2017).
- Consider the genetic effects (such as the potential for outbreeding depression) of moving the species to the new location (genetic research may be needed).
- Ensure that enough individuals can be translocated (factoring in expected mortality rates) to avoid genetic drift and inbreeding depression in the new population (see Pavlik 1996).
- Research and identify (or utilize existing) best germination and transplanting techniques.
    - Consider hiring professional horticulturalists to germinate, transplant, and/or care for/maintain plants.
- Plan for long-term maintenance and monitoring (at least 5 years).

State and Federal permits are required for collecting seeds and vegetative materials on Federal lands. Regardless of land type, follow the best practices outlined by the Center for Plant Conservation (CPC), which include the following (Center for Plant Conservation 2019):

- Collect a maximum of 10% (or other value, as specified by permit) of the available mature seed per population, and non-lethally collect vegetative material (tissue samples, voucher specimens, cuttings, etc.) from no more than 10% of the individual or fruits present in the population.
    - When destruction of the plant is unavoidable, it’s okay to collect 100% of its seeds and to lethally collect 100% of vegetative material for conservation purposes, unless prohibited by the permit.
- Appropriately store collected seeds in a cool, dry, pest-proof environment (or as otherwise determined in coordination with the Service’s species lead) during transport and short-term storage.
- For long-term storage, store seeds collected according to CPC’s recommendations at facilities approved for ex-situ conservation purposes (if needed, coordinate with the Service’s species lead for facility recommendations).

6.1.3.3 Follow-up Monitoring and Adaptive Management Response

Plant populations within (or, if applicable, adjacent to) the project footprint should be monitored or surveyed immediately and then annually, post-project implementation, to track the status and health of the population and to determine if adaptive management may be necessary (Service

1997; Bureau of Land Management 2001; Service 2005a; Service 2005b; Service 2012; Service 2018; Service 2020a). Developing detailed work plans, species management plans, or implementing research on the species' response to project effects is also recommended, if applicable (Service 2009; Service 2005b; Service 2007a; Service 2007b). Follow-up monitoring should result in the following, if applicable:

- An annual report from the action agency or their designated representative to the NMESFO that documents the effectiveness of conservation measures, any mortalities, and potential/suspected causes of any mortality.
- An annual coordination meeting between the action agency and the NMESFO to discuss the report and any actions that need to be implemented to minimize unintended consequences or improve conservation.

Information gleaned through the follow-up monitoring and adaptive management process increases our understanding of a species needs and tolerances as well as the needs and tolerances of its supporting habitats. This information is essential for refining conservation action design and recovering species to the point where they no longer require the safeguards of the Act.

6.1.3.4 Compensatory Mitigation

The goal of compensatory mitigation is to achieve no net loss (see the Service's Mitigation Policy (2023) and Endangered Species Act Compensatory Mitigation Policy (2023)). Compensatory mitigation should be proportional (to the extent, intensity, and duration of residual project impacts), effective (demonstrate measurable conservation benefits above baseline conditions prior to implementing actions that cause impacts), and durable (legally, financially, and otherwise designed for sustained conservation benefit, including monitoring, maintenance, and adaptive management). Given the inherent risks and uncertainties in conservation area management and habitat restoration, anticipate that mitigation ratios will be significantly greater than 1:1 to ensure that no net loss is achieved.

6.1.3.4.1 Protection

We believe that compensatory mitigation for unavoidable, residual effects to rare plants—by permanently protecting plants on currently unprotected lands—is the best form of compensatory mitigation because it results in high confidence, enduring benefits for a species. Specifically, we recommend compensatory mitigation via the acquisition of private lands, the acquisition of conservation easements on private lands, or acquisition of long-term conservation leases on State lands managed for profit.

General recommendations for compensatory mitigation include the following:

- Protect habitat patches that are at least five contiguous acres in size and have low boundary to area ratios[1]. Large, contiguous, non-linear areas (versus small, fragmented, and/or long, linear areas) are necessary to minimize edge effects and better conserve habitat integrity and ecosystem services.
- Create a management plan to ensure that leases, easements, and acquired properties are managed for species conservation.
- Create a trust fund or alternate financial mechanism to ensure that adequate resources are available to implement the management plan.

6.2 Conservation Measures to Mitigate Specific Effects

The following conservation measures summarize previously prescribed conservation measures and recommendations from a selection of biological opinions and biological evaluations pertaining to listed plant species in New Mexico. These are organized according to types of effects that can result from a broad range of activities. To identify potential effects by deconstructed activities, please reference section 5.4 of this document.

6.2.1 Land Clearing and Erosion

Avoidance

- Use pedestrian traffic instead of vehicle traffic in habitat areas (Service 2002; Service 2012).
- Use helicopters instead of vehicles for post-construction inspections, minor maintenance, and repair of the transmission line (Service 2007a).
- Hand string transmission lines in areas of habitat (Service 1985b).

Minimization

- Reduce mechanical equipment paths and turning areas (Service 2020a).
- Use tires adaptable to the terrain, such as sand tires or "terra-tires," which will minimize ground disturbance and erosion (Service 2012; Service 2020b).
- Avoid disturbing areas highly susceptible to erosion; determine appropriate buffer widths in consultation with qualified resource professionals (Service 2002).
- Confine vehicle access to existing roads, when possible (Service 2018).

[1] The length of the boundary of an area relative to the size of the area, expressed as a proportion. Areas which generally conform to a circular or square shape have a low boundary to area ratio.

- Co-locate construction areas within, or as near as practicable, to existing roadways and/or heavily used areas (Service 2007a; Service 2009).
- Maintain project roads following minimum standards for surfacing, rolling the grade, in-sloping, out-sloping, crowning, and installing ditch lead-offs, broad based dips, sediment filters, rock and vegetation energy dissipators, as well as settling ponds; maintain and upgrade culverts to the appropriate minimum size (Service 2020a).

Rectification

- Obscure access points at intersections with paved and improved dirt roads, and re-create the topography and natural barriers (e.g., washes). Design reclamation techniques to specifically address site-specific soil properties and the potential for long-term erosion (Service 2007a; Service 2009).
- Hand-rake spur roads when construction is complete (Service 2007a; Service 2009).
- Restore disturbed areas to the original contour of the land; use hydro-mulch, straw wattles, or coconut coir logs (on steeper slopes) to stabilize soils (Service 2020a).
- Reseed with ecotypic native species to restore cover, using broadcast seeding, no till drill-seeding, or hydro-seeding (Service 2002; Pawelek et al. 2015).

Compensation

- Establish a preserve at a location of occupied, high-quality habitat (Service 2000).
- Provide money to fund on-the-ground conservation activities (Service 2018).

6.2.2 Invasive Species Establishment

Avoidance

- Avoid areas with noxious and invasive weeds, except for when using treatments that may be designed to reduce weed populations (Service 2020a).

Minimization

- Reseed with ecotypic native species to reduce invasive establishment, using broadcast seeding, no till drill-seeding, or hydro-seeding (Service 2002; Pawelek et al. 2015).
- Pneumatically clean equipment before entry into the action area and when coming from areas with invasives (Service 2007a; Service 2009; Service 2018; Service 2020a).
- Use natives or non-persistent non-natives for re-vegetation projects (Service 2005a).
- Follow established weed control plans (Service 2005a; Service 2009).

Rectification:

- Post-action, control weeds within disturbed areas (Service 2009).

6.2.3 Soil Compaction

Avoidance

- Prohibit machinery and vehicles in habitat areas, including construction and maintenance machinery (Service 1985b).
- Avoid equipment use in fine-textured soils (Adams et al. 1982).
- Prohibit off-road equipment travel when soils are moist and vulnerable to compaction and erosion (Service 2020b).

Minimization

- Reduce mechanical equipment paths and turning areas (Service 2020a).
- Restrict all traffic to the ROW, designated work areas, and authorized access roads. Strictly prohibit cross-country travel (Service 2007a; Service 2009).
- Exclude grazing from occupied plant habitat that has high potential for trampling (e.g., close to existing waters, gathering areas, and/or cattle travel ways) or where forage use monitoring indicates a declining trend in habitat over several (3–5) years (Service 2007b; Service 2008).
- Annually protect newly emerging seedlings from trampling (Service 2005a).

Rectification

- Use organic compound amendments (Díaz-Zorita and Grosso 2000).
- Rip scraped areas to loosen compacted soils and chain-drag to remove tracks (Service 2007a).

6.2.4 Dust Generation

Avoidance

- Avoid off-road vehicle travel when wind speeds are high (i.e., above 20 mph) to reduce soil disturbance and fugitive dust (Service 2020b).

Minimization

- Limit off-road vehicle travel to speeds less than 15 mph (Service 2020b).
- Maintain project roads following minimum standards for surfacing (Service 2020a).
- Use dust abatement treatments (i.e., spray water on road daily or apply a magnesium chloride treatment once a year) (U.S. Forest Service 1989).

6.2.5 Altered Hydrology

Avoidance

- Establish a buffer of sufficient width to absorb and prevent sediment flow that could plug or alter water flow through occupied travertine deposits (Service 2002; Service 2005b).

Minimization

- Minimize water diversions and watershed degradation (Service 2005a).

Rectification

- Conduct a post-action evaluation of hydrology/drainage alterations; evaluate portions of access roads across washes to determine if natural drainage patterns have been altered (Service 2007a).
- Repair roadway with hand tools to re-establish natural drainage patterns (Service 2007a).

6.2.6 Destructive Human Activities

Avoidance

- Install locked gates at transmission line access roads (Service 2007a).
- Advise permittees to keep vehicles outside of enclosed areas to prevent the formation of tracks and reduce the chance of damaging plants (Service 2008).

Minimization

- Post signage to discourage public access/indicate ecologically sensitive species or area (Service 1984).
- Regulate off-road vehicle (ORV) use in habitat in the vicinity of the constructed road and/or outside of established routes (Service 1985a; Service 2005a).
- Educate law enforcement officers in identifying suspicious collection-related activity; report suspicious collection-related activity (Service 2007b; Service 2008).

6.2.7 Potential Spills

Minimization

- Implement spill prevention plans and utilize spill containment materials, such as using impermeable containment berms and absorbent pads in staging areas designed for refueling (Service 2020a).

Rectification

- Determine via emergency consultation, as appropriate.

Compensation

- Determine via emergency consultation, as appropriate.

6.2.8 Pesticide Treatment Impacts

Avoidance

- Avoid pesticide use in areas occupied by pollinators; if insect outbreaks must be controlled, use alternative methods (Service 2005a).

Minimization

- Adhere to pesticide use guidelines in "Recommended Protection Measures for Pesticide Applications in Region 2 of the U.S. Fish and Wildlife Service" (Service 2005a).
- Follow established protocols for wind speed and timing of application, calibration of equipment, using proper nozzle tips, and careful handling (Service 2018).
- Observe site conditions and match herbicides and application methods to site, species to be controlled, season, presence of sensitive environmental areas, proximity of non-target species, and vegetation conditions, including height (2018 Service).

7 What to Do in the Event of Unintended Damage to Listed Plants or Designated Critical Habitat

If damage to plants or essential designated critical habitat features is discovered, please report the following information to:

New Mexico Ecological Services Field Office (NMESFO)
Address: 2105 Osuna Road NE, Albuquerque, NM 87113-100
E-mail: nmesfo@fws.gov
Phone: (505) 346-2525
Toll Free: (800) 299-0196

- Date of incident
- Name
- E-mail
- Phone number
- Location coordinates
- Coordinate system
- Species or essential physical and biological features of designated critical habitat affected
- Cause of damage
- Estimated area affected (include unit of measure)
- Estimated number of individuals affected
- Agency response

Additionally, check your Federal permit or biological opinion for any action agency requirements, such as “stop work” terms and conditions. Finally, assess if you need to initiate or reinitiate consultation (see 50 CFR §402.16, Reinitiation of consultation).

8 Literature Cited

Ackerman, D. E., and J. C. Finlay. 2019. Road dust biases NDVI and alters edaphic properties in Alaskan arctic tundra. *Scientific Reports* 9: 1–8.

Adams, J. A., A. S. Endo, L. H. Stolzy, P. G. Rowlands, and H. B. Johnson. 1982. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. *Journal of Applied Ecology* 19: 167–175.

Aguilar, R., E. J. Cristóbal-Pérez, F. J. Balvino-Olvera, M. Aguilar-Aguilar, N. Aguirre-Acosta, L. Ashworth, J. A. Lobo, S. Martén-Rodríguez, et al. 2019. Habitat fragmentation reduces plant progeny quality: A global synthesis. *Ecology Letters* 22: 1163–1173.

Aizen, M. A., L. A. Garibaldi, S. A. Cunningham, and A. M. Klein. 2009. How much does agriculture depend on pollinators? Lessons from long-term trends in crop production. *Annals of Botany* 103: 1579–1588.

Allington, G. R. H., and T. J. Valone. 2010. Reversal of desertification: The role of physical and chemical soil properties. *Journal of Arid Environments* 74: 973–977.

Allred, B. W., W. K. Smith, D. Twidwell, J. H. Haggerty, S. W. Running, D. E. Naugle, and S. D. Fuhlendorf. 2015. Ecosystem services lost to oil and gas in North America. *Science* 348: 401–402.

Angold, P. G. 1997. The impact of a road upon adjacent heathland vegetation: Effects on plant species composition. *The Journal of Applied Ecology* 34: 409–417.

Auerbach, N. A., M. D. Walker, and D. A. Walker. 1997. Effects of roadside disturbance on substrate and vegetation properties in arctic tundra. *Ecological Applications* 7: 218–235.

Bacles, C. F. E., A. J. Lowe, and R. A. Ennos. 2004. Genetic effects of chronic habitat fragmentation on tree species: The case of Sorbus aucuparia in a deforested Scottish landscape. *Molecular Ecology* 13: 573–584.

Balasubramaniyam, A., and P. J. Harvey. 2014. Scanning electron microscopic investigations of root structural modifications arising from growth in crude oil-contaminated sand. *Environmental Science and Pollution Research* 21: 12651–12661.

Ballantyne, M., and C. M. Pickering. 2015. The impacts of trail infrastructure on vegetation and soils: Current literature and future directions. *Journal of Environmental Management* 164: 53–64.

Baruah, P., R. R. Saikia, P. P. Baruah, and S. Deka. 2014. Effect of crude oil contamination on the chlorophyll content and morpho-anatomy of Cyperus brevifolius (Rottb.) Hassk. *Environmental Science and Pollution Research* 21: 12530–12538.

Beck, K. G. 2014. Invasive species: Herbicides can facilitate a positive outcome for invasive and endangered species interactions. *Outlooks on Pest Management* 25: 316–319.

Beley, J. R., T. M. Ditsworth, S. M. Butt, and C. D. Johnson. 1982. Arthropods, plants and transmission lines in Arizona: Community dynamics during secondary succession in a pinyon-juniper chaparral habitat. *The Southwestern Naturalist* 27: 325.

Biasotto, L. D., and A. Kindel. 2018. Power lines and impacts on biodiversity: A systematic review. *Environmental Impact Assessment Review* 71: 110–119.

Bish, M., E. Oseland, and K. Bradley. 2020. Off-target pesticide movement: A review of our current understanding of drift due to inversions and secondary movement. *Weed Technology* 35: 345–356.

Bolinger, M., and G. Bolinger. 2022. Land requirements for utility-scale PV: An empirical update on power and energy density. *IEEE Journal of Photovoltaics* 12: 589–594.

Boutin, C., B. Strandberg, D. Carpenter, S. K. Mathiassen, and P. J. Thomas. 2014. Herbicide impact on non-target plant reproduction: What are the toxicological and ecological implications? *Environmental Pollution* 185: 295–306.

Bradley, B. A., and J. F. Mustard. 2006. Characterizing the landscape dynamics of an invasive plant and risk of invasion using remote sensing. *Ecological Applications* 16: 1132–1147.

Bradley, H. S., S. Tomlinson, M. D. Craig, A. T. Cross, and P. W. Bateman. 2022. Mitigation translocation as a management tool. *Conservation Biology* 36: (Article e13667) 1-11.

Brisson, J., S. de Blois, and C. Lavoie. 2010. Roadside as invasion pathway for common reed (Phragmites australis). *Invasive Plant Science and Management* 3: 506–514.

Bureau of Land Management. 2001. *Hook Ranch biological evaluation*. Consultation Number 2-22-01-1-180. Las Cruces, New Mexico: Bureau of Land Management, Las Cruces District Office.

Castellano, M. J., and T. J. Valone. 2007. Livestock, soil compaction and water infiltration rate: Evaluating a potential desertification recovery mechanism. *Journal of Arid Environments* 71: 97–108.

Center for Plant Conservation. 2019. *CPC Best Plant Conservation Practices to Support Species Survival in the Wild*. Escondido, California: Center for Plant Conservation.

Çoban, S., S. Balekoğlu, and G. Özalp. 2019. Change in plant species composition on powerline corridor: A case study. *Environmental Monitoring and Assessment* 191: (Article 200) 1-13.

Cole, D. N. 1986. *Resource impacts caused by recreation: A literature review*. INT4901 Publication #165. Missoula, Montana: The President's Commission on American Outdoors.

Cowie, B. A., C. M. Thornton, and B. J. Radford. 2007. The Brigalow Catchment Study: I. Overview of a 40-year study of the effects of land clearing in the Brigalow bioregion of Australia. *Soil Research* 45: 479–495.

Culley, T. M., and T. C. Grubb. 2003. Genetic effects of habitat fragmentation in Viola pubescens (Violaceae), a perennial herb with chasmogamous and cleistogamous flowers. *Molecular Ecology* 12: 2919–2930.

Cunningham, S. A. 2000. Depressed pollination in habitat fragments causes low fruit set. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 267: 1149–1152.

Davis, B. N. K., and C. T. Williams. 1990. Buffer zone widths for honeybees from ground and aerial spraying of insecticides. *Environmental Pollution* 63: 247–259.

Dawson, S. J., P. J. Adams, K. I. Waddington, K. E. Moseby, and P. A. Fleming. 2019. Recovery of Pindan vegetation on seismic lines. *The Rangeland Journal* 41: 393–403.

DeFalco, L. A., T. C. Esque, J. M. Kane, and M. B. Nicklas. 2009. Seed banks in a degraded desert shrubland: Influence of soil surface condition and harvester ant activity on seed abundance. *Journal of Arid Environments* 73: 885–893.

Desserud, P. A., and M. A. Naeth. 2013. Natural recovery of rough fescue (Festuca hallii (Vasey) Piper) grassland after disturbance by pipeline construction in central Alberta, Canada. *Natural Areas Journal* 33: 91–98.

Díaz-Zorita, M., and G. A. Grosso. 2000. Effect of soil texture, organic carbon and water retention on the compactability of soils from the Argentinean pampas. *Soil and Tillage Research* 54: 121–126.

Dueñas, M.-A., H. J. Ruffhead, N. H. Wakefield, P. D. Roberts, D. J. Hemming, and H. Diaz-Soltero. 2018. The role played by invasive species in interactions with endangered and threatened species in the United States: A systematic review. *Biodiversity and Conservation* 27: 3171–3183.

Duncan, D. H., A. B. Nicotra, J. T. Wood, and S. A. Cunningham. 2004. Plant isolation reduces outcross pollen receipt in a partially self-compatible herb. *Journal of Ecology* 92: 977–985.

Elmore, A. J., S. J. Manning, J. F. Mustard, and J. M. Craine. 2006. Decline in alkali meadow vegetation cover in California: The effects of groundwater extraction and drought. *Journal of Applied Ecology* 43: 770–779.

Erickson, A. M., R. G. Lym, and D. Kirby. 2006. Effect of herbicides for leafy spurge control on the western prairie fringed orchid. *Rangeland Ecology & Management* 59: 462–467.

Etyemezian, V., S. Ahonen, D. Nikolic, J. Gillies, H. Kuhns, D. Gillette, and J. Veranth. 2004. Deposition and removal of fugitive dust in the arid southwestern United States: Measurements and model results. *Journal of the Air & Waste Management Association* 54: 1099–1111.

Fahselt, D. 1988. The dangers of transplantation as a conservation technique. *Natural Areas Journal* 8: 238–243.

Farmer, A. M. 1993. The effects of dust on vegetation: A review. *Environmental Pollution* 79: 63–75.

Fiedler, P. L. 1991. *Mitigation-related transplantation, relocation and reintroduction projects involving endangered and threatened, and rare plant species in California*. Final Report. Sacramento, California: California Department of Fish & Game, Endangered Plant Program.

Fischer, J., and D. B. Lindenmayer. 2007. Landscape modification and habitat fragmentation: A synthesis. *Global Ecology and Biogeography* 16: 265–280.

Fischer, M., and D. Matthies. 1997. Mating structure and inbreeding and outbreeding depression in the rare plant Gentianella germanica (Gentianaceae). *American Journal of Botany* 84: 1685–1692.

Foré, S. A., R. J. Hickey, J. L. Vankat, S. I. Guttman, and R. L. Schaefer. 1992. Genetic structure after forest fragmentation: A landscape ecology perspective on Acer saccharum. *Canadian Journal of Botany* 70: 1659–1668.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29: 207-C2.

Galloway, D. L., and T. J. Burbey. 2011. Review: Regional land subsidence accompanying groundwater extraction. *Hydrogeology Journal* 19: 1459–1486.

Godefroid, S., C. Piazza, G. Rossi, S. Buord, A.-D. Stevens, R. Aguraiuja, C. Cowell, C. W. Weekley, et al. 2011. How successful are plant species reintroductions? *Biological Conservation* 144: 672–682.

Goodell, K., D. R. Elam, J. D. Nason, and N. C. Ellstrand. 1997. Gene flow among small populations of a self-incompatible plant: An interaction between demography and genetics. *American Journal of Botany* 84: 1362–1371.

Gurevitch, J., and D. Padilla. 2004. Are invasive species a major cause of extinctions? *Trends in Ecology & Evolution* 19: 470–474.

Hasselquist, N. J., and M. F. Allen. 2009. Increasing demands on limited water resources: Consequences for two endangered plants in Amargosa Valley, USA. *American Journal of Botany* 96: 620–626.

Hawrot-Paw, M., A. Wijatkowski, and M. Mikiciuk. 2015. Influence of diesel and biodiesel fuel-contaminated soil on microorganisms, growth and development of plants. *Plant, Soil and Environment* 61: 189–194.

Hettiaratchi, D. R. P. 1990. Soil compaction and plant root growth. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 329: 343–355.

Hewitt, A. J., D. R. Johnson, J. D. Fish, C. G. Hermansky, and D. L. Valcore. 2002. Development of the spray drift task force database for aerial applications. *Environmental Toxicology and Chemistry* 21: 648–658.

Honnay, O., and H. Jacquemyn. 2007. Susceptibility of common and rare plant species to the genetic consequences of habitat fragmentation. *Conservation Biology* 21: 823–831.

Honnay, O., K. Verheyen, J. Butaye, H. Jacquemyn, B. Bossuyt, and M. Hermy. 2002. Possible effects of habitat fragmentation and climate change on the range of forest plant species. *Ecology Letters* 5: 525–530.

Honnay, O., H. Jacquemyn, B. Bossuyt, and M. Hermy. 2005. Forest fragmentation effects on patch occupancy and population viability of herbaceous plant species. *New Phytologist* 166: 723–736.

Hunter, R., F. B. Turner, R. G. Lindberg, and K. B. Hunter. 1987. Effects of land clearing on bordering winter annual populations in the Mohave Desert. *The Great Basin Naturalist* 47: 234–238.

Isichei, A. O. 2014. Effects of oil industry operations on vegetation in Nigeria. In *Environmental Monitoring and Impact Assessment*, ed. A. F. Oluwole, Asublojo, I. B. Obioh, and O. J. Ogunsola, 258–269. Lagos, Nigeria: Seems Nig. Ltd.

IUCN-SSC, R. 2013. *Guidelines for reintroductions and other conservation translocations*. Versoin 1.0. Gland, Switzerland: IUCN Species Survival Commission.

Jolly, I. D., K. L. McEwan, and K. L. Holland. 2008. A review of groundwater-surface water interactions in arid/semi-arid wetlands and the consequences of salinity for wetland ecology. *Ecohydrology* 1: 43–58.

Jones, I. L., J. W. Bull, E. J. Milner-Gulland, A. V. Esipov, and K. B. Suttle. 2014. Quantifying habitat impacts of natural gas infrastructure to facilitate biodiversity offsetting. *Ecology and Evolution* 4: 79–90.

Jones, N. F., and L. Pejchar. 2013. Comparing the ecological impacts of wind and oil & gas development: A landscape scale assessment. *PLOS ONE* 8: (Article e81391) 1-12.

Kameswaran, S., Y. Gunavathi, and P. G. Krishna. 2019. Dust pollution and its influence on vegetation: A critical analysis. *Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences* 5: 341–363.

Kunin, W. E. 1997. Population size and density effects in pollination: Pollinator foraging and plant reproductive success in experimental arrays of Brassica kaber. *The Journal of Ecology* 85: 225–234.

Lathrop, E. W., and E. F. Archbold. 1980. Plant response to Los Angeles aqueduct construction in the Mojave desert. *Environmental Management* 4: 137–148.

Lehmkuhl, J. F., and L. F. Ruggiero. 1991. Forest fragmentation in the Pacific Northwest and its potential effects on wildlife. In *Wildlife and Vegetation of Unmanaged Douglas-Fir Forests.*, ed. L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff. General Technical Report PNW-GTR-285. Portland, Oregon: USDA Forest Service, Pacific Northwest Research Station.

Lennartsson, T. 2002. Extinction thresholds and disrupted plant-pollinator interactions in fragmented plant populations. *Ecology* 83: 3060–3072.

Lewis, M. B., E. W. Schupp, and T. A. Monaco. 2017. Road dust correlated with decreased reproduction of the endangered Utah shrub Hesperidanthus suffrutescens. *Western North American Naturalist* 77: 430–439.

Li, J., G. S. Okin, L. Alvarez, and H. Epstein. 2007. Quantitative effects of vegetation cover on wind erosion and soil nutrient loss in a desert grassland of southern New Mexico, USA. *Biogeochemistry* 85: 317–332.

Maschinski, J., and M. A. Albrecht. 2017. Center for Plant Conservation's best practice guidelines for the reintroduction of rare plants. *Plant Diversity* 39: 390–395.

Matarczyk, J. A., A. J. Willis, J. A. Vranjic, and J. E. Ash. 2002. Herbicides, weeds and endangered species: Management of Bitou bush (Chrysanthemoides monilifera ssp. rotundata) with glyphosate and impacts on the endangered shrub, Pimelea spicata. *Biological Conservation* 108: 133–141.

McManamen, C., C. R. Nelson, and V. Wagner. 2018. Timing of seeding after herbicide application influences rates of germination and seedling biomass of native plants used for grassland restoration. *Restoration Ecology* 26: 1137–1148.

Menges, E. S. 1991. Seed germination percentage increases with population size in a fragmented prairie species. *Conservation Biology* 5: 158–164.

Miller, L. M., and D. W. Keith. 2018. Climatic impacts of wind power. *Joule* 2: 2618–2632.

Mitchell, J. 2009. Power lines and catastrophic wildland fire in Southern California. In *Conference Proceedings, 11th International Conference and Exhibition: 26-28 January,* *2009, Fisherman's Wharf, San Francisco, USA*. United Kingdom: Interscience Communications.

Mittelhauser, J. R., P. W. Barnes, and T. G. Barnes. 2011. The effect of herbicide on the re-establishment of native grasses in the Blackland Prairie. *Natural Areas Journal* 31: 226–233.

Morgan, J. W. 1999. Effects of population size on seed production and germinability in an endangered, fragmented grassland plant. *Conservation Biology* 13: 266–273.

Mustajärvi, K., P. Siikamäki, S. Rytkönen, and A. Lammi. 2001. Consequences of plant population size and density for plant-pollinator interactions and plant performance. *Journal of Ecology* 89: 80–87.

Myers-Smith, I. H., B. K. Arnesen, R. M. Thompson, and F. S. Chapin. 2006. Cumulative impacts on Alaskan arctic tundra of a quarter century of road dust. *Ecoscience* 13: 503–510.

Naeth, M. A., D. A. Locky, S. R. Wilkinson, C. L. Bryks, C. H. Low, and M. R. Nannt. 2020a. Influence of pipelines and environmental factors on the endangered plant, Halimolobos virgata (Nutt.) O.E. Schultz over a 10 year period. *Botany* 98: 735–746.

Naeth, M. A., D. A. Locky, S. R. Wilkinson, M. R. Nannt, C. L. Bryks, and C. H. Low. 2020b. Pipeline impacts and recovery of dry mixed-grass prairie soil and plant communities. *Rangeland Ecology & Management* 73: 619–628.

Nawaz, M. F., G. Bourrié, and F. Trolard. 2013. Soil compaction impact and modelling: A review. *Agronomy for Sustainable Development* 33: 291–309.

Neldner, V. J., M. J. Laidlaw, K. R. McDonald, M. T. Mathieson, R. I. Melzer, R. Seaton, W. J. F. McDonald, R. Hobson, et al. 2017. *Scientific review of the impacts of land clearing on threatened species in Queensland*. Brisbane, Queensland, Australia: Queensland Government.

Ochege, F. U., R. T. George, E. C. Dike, and C. Okpala-Okaka. 2017. Geospatial assessment of vegetation status in Sagbama oilfield environment in the Niger Delta region, Nigeria. *The Egyptian Journal of Remote Sensing and Space Science* 20: 211–221.

Olson, E. R., and J. M. Doherty. 2012. The legacy of pipeline installation on the soil and vegetation of southeast Wisconsin wetlands. *Ecological Engineering* 39: 53–62.

Ong, S., C. Campbell, P. Denholm, R. Margolis, and G. Heath. 2013. *Land-use requirements for solar power plants in the United States*. Golden, Colorado: National Renewable Energy Lab (NREL).

Otton, J. K., R. A. Zielinski, B. D. Smith, M. M. Abbott, and B. D. Keeland. 2005. Environmental impacts of oil production on soil, bedrock, and vegetation at the U.S.

Geological Survey Osage–Skiatook Petroleum Environmental Research site A, Osage County, Oklahoma. *Environmental Geosciences* 12: 73–87.

Pavlik, B. M. 1996. Defining and measuring success. In *Restoring Diversity: Strategies for the Reintroduction of Endangered Plants*, 127–155. Island Press: Washington, DC.

Pawelek, K. A., F. S. Smith, A. D. Falk, M. K. Clayton, K. W. Haby, and D. W. Rankin. 2015. Comparing three common seeding techniques for pipeline vegetation restoration: A case study in south Texas. *Rangelands* 37: 99–105.

Pichtel, J. 2016. Oil and gas production wastewater: Soil contamination and pollution prevention. *Applied and Environmental Soil Science* 2016: 1–24.

Pierre, J. P., B. D. Wolaver, B. J. Labay, T. J. LaDuc, C. M. Duran, W. A. Ryberg, T. J. Hibbitts, and J. R. Andrews. 2018. Comparison of recent oil and gas, wind energy, and other anthropogenic landscape alteration factors in Texas through 2014. *Environmental Management* 61: 805–818.

Raiter, K. G., S. M. Prober, H. P. Possingham, F. Westcott, and R. J. Hobbs. 2018. Linear infrastructure impacts on landscape hydrology. *Journal of Environmental Management* 206: 446–457.

Ravi, S., D. D. Breshears, T. E. Huxman, and P. D’Odorico. 2010. Land degradation in drylands: Interactions among hydrologic–aeolian erosion and vegetation dynamics. *Geomorphology* 116: 236–245.

Richardson, M. L., B. A. Wilson, D. A. S. Aiuto, J. E. Crosby, A. Alonso, F. Dallmeier, and G. K. Golinski. 2017. A review of the impact of pipelines and power lines on biodiversity and strategies for mitigation. *Biodiversity and Conservation* 26: 1801–1815.

Rubino, D. L., C. E. Williams, and W. J. Moriarity. 2002. Herbaceous layer contrast and alien plant occurrence in utility corridors and riparian forests of the Allegheny High Plateau. *Journal of the Torrey Botanical Society* 129: 125–135.

Ryabuhina, M. V., R. A. Maiski, and R. G. Kalyakina. 2019. Transboundary air pollution and its effects on vegetation. *IOP Conference Series: Materials Science and Engineering* 687: (Article 066043) 1-7.

Severns, P. 2003. Inbreeding and small population size reduce seed set in a threatened and fragmented plant species, Lupinus sulphureus ssp. kincaidii (Fabaceae). *Biological Conservation* 110: 221–229.

Shapiro, K., S. Khanna, and S. Ustin. 2016. Vegetation impact and recovery from oil-induced stress on three ecologically distinct wetland sites in the Gulf of Mexico. *Journal of Marine Science and Engineering* 4: (Article 33) 1-19.

Sharifi, M. R., A. C. Gibson, and P. W. Rundel. 1997. Surface dust impacts on gas exchange in Mojave Desert shrubs. *The Journal of Applied Ecology* 34: 837–846.

Singh, J., A. Salaria, and A. Kaul. 2015. Impact of soil compaction on soil physical properties and root growth: A review. *International Journal of Food, Agriculture and Veterinary Sciences* 5: 23–32.

Soon, Y. K., M. A. Arshad, W. A. Rice, and P. Mills. 2000. Recovery of chemical and physical properties of boreal plain soils impacted by pipeline burial. *Canadian Journal of Soil Science* 80: 489–497.

Steffan-Dewenter, I., and T. Tscharntke. 1999. Effects of habitat isolation on pollinator communities and seed set. *Oecologia* 121: 432–440.

Stoessel, F., T. Sonderegger, P. Bayer, and S. Hellweg. 2018. Assessing the environmental impacts of soil compaction in life cycle assessment. *Science of The Total Environment* 630: 913–921.

Stromberg, J. C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. *Ecological Applications* 6: 113–131.

Thomson, D. 2005. Measuring the effects of invasive species on the demography of a rare endemic plant. *Biological Invasions* 7: 615–624.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14: 18–30.

Tyser, R. W., and C. A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). *Conservation Biology* 6: 253–262.

U.S. Department of the Interior, and U.S. Department of Agriculture. 2007. *The gold book: Surface operating standards and guidelines for oil and gas exploration and development*. BLM/WO/ST-06/021+ 3071/REV 07. Denver, Colorado: Bureau of Land Management.

U.S. Environmental Protection Agency. 2012. *Global anthropogenic non-CO2 greenhouse gas emissions: 1990-2030*. EPA 430-R-12-006. Washington, D.C.: U.S. Environmental Protection Agency, Office of Atmospheric Programs, Climate Change Division.

U.S. Environmental Protection Agency. 2015a. Class II oil and gas related injection wells. Overviews and Factsheets. *Underground Injection Control (UIC)*. https://www.epa.gov/uic/class-ii-oil-and-gas-related-injection-wells (Accessed June 1, 2023).

U.S. Environmental Protection Agency. 2015b. TENORM: Oil and gas production wastes. Overviews and Factsheets. *Radiation Protection*. https://www.epa.gov/radiation/tenorm-oil-and-gas-production-wastes (Accessed June 1, 2023).

U.S. Fish and Wildlife Service and National Marine Fisheries Service (Services). 1998. *Endangered species consultation handbook: Procedures for conducting consultation and conference activities under section 7 of the Endangered Species Act*. Washington, D.C.: U.S. Fish and Wildlife Service and National Marine Fisheries Service.

U.S. Fish and Wildlife Service (Service). 1984. *Draft biological opinion for the proposed fencing of Federal lands containing a small population of Knowlton cactus (Pediocactus knowltonii), San Juan County, New Mexico (Mr. Millenbach's July 10, 1984 letter) (BLM)*. Consultation Number 2-22-84-F-074. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 1985a. *Biological opinion: Navajo road project N36(5) 2 and 4 (BIA)*. Consultation Number 12-22-83-F-039. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 1985b. *Biological opinion: Powerline relocation and the gypsum wild buckwheat (Eriogonum gypsophilum), Eddy County, New Mexico (BLM)*. Consultation Number 2-22-85-F-038. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 1997. *Biological opinion on continued implementation of the Farmington Resource Management Plan*. Consulation Number 2-22-96-F-010. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, Southwest Region Headquarters Office.

U.S. Fish and Wildlife Service (Service). 2000. *Biological opinion on the effects of the Shiprock Northern Navajo Fairgrounds project on Mesa Verde cactus*. Consultation Number 2-22-99-F-467. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2002. *Summary: Final biological and conference opinion on the effects to the Mexican spotted owl and Sacramento Mountains checkerspot butterfly from the proposal to implement the Penasco II vegetation management project and forest plan amendment, Sacramento Ranger District, Otero County, New Mexico*. Consultation Number 2-22-02-F-397. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2005a. *Programmatic biological and conference opinion: The continued implementation of the land and resource management plans for the eleven national forests and national grasslands of the Southwestern Region*. Consultation Number 2-22-03-F-366. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, Southwest Region Headquarters Office.

U.S. Fish and Wildlife Service (Service). 2005b. *Summary: Final biological opinion on the effects to Mexican spotted owl from the proposal to implement the Rio Penasco II non-programmatic vegetation management project and forest plan amendment, Sacramento*

Ranger District, Lincoln National Forest, New Mexico. Consultation Number 2-22-02-F-397. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2007a. *Biological opinion for the Navajo transmission project*. Consultation Number 22410-1993-F-0330. Phoenix, Arizona: U.S. Fish and Wildlife Service, Arizona Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2007b. *Summary: Biological opinion on the effects to the Kuenzler hedgehog cactus (Echinocereus fendleri var. kuenzler) from the Panama/Prude allottment*. Consultation Number 22420-2006-F-0138. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2008. *Summary: Biological opinion on the effects to Kuenzler hedgehog cactus from the proposal to issue a 10-year grazing permit on the Vera Cruz and Latham allottments, Smokey Bear Ranger District, Lincoln National Forest, New Mexico*. Consultation Number 22420-2007-F-0089. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2009. *Final biological opinion for the Navajo-Gallup water supply project, U.S. Bureau of Reclamation, Durango, Colorado*. Consultation Number 2-22-01-F-532. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2012. *Concurrence letter regarding activities associated with a three dimensional geophysical survey in southern Eddy County, New Mexico*. Consultation Number 02ENNMOO-2012-I-Olll. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2018. *Final biological opinion for WAPA's programmatic operation and maintenance in the Four Corners region of Colorado, New Mexico, Arizona, and Utah*. Consultation Number 02ENNM00-2019-F-0206. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2020a. *Biological opinion for northern New Mexico riparian, aquatic, and wetland restoration project*. Consultation Number 02ENNM00-2020-F-0337. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2020b. *Informal consultation for the barricade fencing for gypsum wild buckwheat*. Consultation Number 02ENNM00-2020-I-0978. Albuquerque, New Mexico: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office.

U.S. Fish and Wildlife Service (Service). 2023a. Endangered Species Act Compensatory Mitigation Policy (501 FW 3, Appendix 1).

U.S. Fish and Wildlife Service (Service). 2023b. Mitigation Policy (501 FW 2, Appendix 1).

U.S. Forest Service. 1989. *Request for informal consultation on the effects of the Six Mile timber sale on Zuni fleabane (Erigeron rhizomatus)*. Grants, New Mexico: U.S. Forest Service, Mt. Taylor Ranger District.

U.S. Forest Service. 2010. *Environmental assessment for integrated pest management of noxious/invasive plants: Cibola National Forest, Catron, Cibola, Colfax, Harding, Lincoln, McKinley, Mora, Sandoval, Sierra, Socorro, Torrance, Union and Valencia Counties in New Mexico; Cimarron County in Oklahoma; Dallam County in Texas*. Environmental Assessment MB-R3-03-10. Santa Fe, New Mexico: U.S. Forest Service, Southwestern Region Office.

U.S. Forest Service. 2018. *Final environmental impact statement for the invasive plant control project: Carson and Santa Fe National Forests in Colfax, Los Alamos, Mora, Rio Arriba, San Miguel, Santa Fe, Sandoval, and Taos Counties, New Mexico*. Environmental Impact Statement MB-R3-10-26. Santa Fe, New Mexico: U.S. Forest Service, Southwestern Region Office.

Vardaka, E., C. M. Cook, T. Lanaras, S. P. Sgardelis, and J. D. Pantis. 1995. Effect of dust from a limestone quarry on the photosynthesis of Quercus coccifera, an evergreen schlerophyllous shrub. *Bulletin of Environmental Contamination and Toxicology* 54: 414–419.

Wagner, V., and C. R. Nelson. 2014. Herbicides can negatively affect seed performance in native plants. *Restoration Ecology* 22: 288–291.

Walker, L. R., and S. D. Smith. 1997. Impacts of invasive plants on community and ecosystem properties. In *Assessment and Management of Plant Invasions*, ed. J. O. Luken and J. W. Thieret, 69–86. Springer Series on Environmental Management. New York, New York: Springer.

White, D. D., M. T. Waskey, G. P. Brodehl, and P. E. Foti. 2006. A comparative study of impacts to mountain bike trails in five common ecological regions of the southwestern U.S. *Journal of Park and Recreation Administration* 24: 21–41.

White, J. A. 2007. *Recommended protection measures for pesticide applications in Region 2 of the U.S. Fish and Wildlife Service*. Austin, Texas: U.S. Fish and Wildlife Service, Region 2, Environmental Contaminants Program.

Winder, S. 2012. *Conserving native pollinators: A literature review considering the appropriate use of buffers around Colorado rare plants*. Lakewood, Colorado: Bureau of Land Management, Colorado State Office.

Xiao, J., Y.-F. Wang, P. Shi, L. Yang, and L.-D. Chen. 2014. Potential effects of large linear pipeline construction on soil and vegetation in ecologically fragile regions. *Environmental Monitoring and Assessment* 186: 8037–8048.

Young, A. G., H. G. Merriam, and S. I. Warwick. 1993. The effects of forest fragmentation on genetic variation in Acer saccharum Marsh. (sugar maple) populations. *Heredity* 71: 277–289.

Zhang, K., Y. Shi, X. Cui, P. Yue, K. Li, X. Liu, B. M. Tripathi, and H. Chu. 2019. Salinity is a key determinant for soil microbial communities in a desert ecosystem. *mSystems* 4: (Article e00225-18) 1-11.

Zhang, W., C. Wang, R. Xue, and L. Wang. 2019. Effects of salinity on the soil microbial community and soil fertility. *Journal of Integrative Agriculture* 18: 1360–1368.

Appendix A   Species Summaries for Federally Listed Plant Species in New Mexico

Photo Credit: Robert Sivinski 2004

Prepared By:

Institute for Applied Ecology

For:

U.S. Fish & Wildlife Service

New Mexico Ecological Services Field Office

May 2024

Page intentionally left blank.

Table of Contents

List of Tables

A.1 Introduction

Species summaries for federally listed plant species in New Mexico, contained herein, provide a framework for evaluating threats and developing conservation strategies to maintain population viability across each species' range. Many of the federally listed plant species in New Mexico are naturally rare due to restricted range size, high degree of habitat specificity or endemism, and small local population sizes (Rabinowitz 1981). Threats to federally listed plant species from natural and anthropogenic sources increase the vulnerability of these naturally rare species to extinction. When a proposed project has potential to impact a federally listed species, this framework can be applied to make decisions about effect determinations and conservation measures during consultations under section 7 of the Act. These summaries can also be used to inform recovery actions, assess knowledge gaps, and prioritize research.

These species summaries may become outdated as additional information becomes available. The Services identifies new, relevant species information in five-year reviews, which can be found within species' ECOS profiles. Links to species' ECOS profiles are included in official IPaC species lists. You may also inquire with Service species leads about new species information. A list of species leads by species can be located at https://www.fws.gov/office/new-mexico-ecological-services/species.

Species summaries *within this document* include the following components:

- **General Summary:** Broad overview of the species' distribution, physical description, and life history.
- **Threats:** List of known threats to the species.
- **Recovery and Conservation Needs:** List of needed actions identified to promote species recovery.
- **Species Needs Table:** A compilation of information related to species' requirements for reproduction, recruitment, survival, persistence, and resilience of individuals and populations.

Contact New Mexico Services Field Office species leads for species' bibliographic references. For additional information for each species, please see the corresponding species profile on ECOS.

A.1.1 Species Needs

Species needs, as presented in these species' summaries, are based on concepts of population viability, or the likelihood of persistence of a population over a specified time period and geographic area. Species needs are related to the basic ecological and biological functions of individuals and populations that are required for survival, reproduction, recruitment, and persistence.

The species needs tables include information summarized under the following categories:

- Reproduction
  - **Breeding System.** The mechanism by which species reproduce, sexually (via outcrossing or selfing) or asexually (via vegetative clonality).
  - **Reproductive Season.** The timing of reproductive life history stages (i.e., flower budding to seed set).
  - **Pollinators.** If relevant, the taxa that have been observed visiting or pollinating flowers.
- Seed Dispersal
  - **Mechanisms/Agents.** The agent or mechanism by which seed is dispersed away from the parent plant.
  - **Distance.** The estimated or known distance a seed is likely to be dispersed away from the parent plant based on dispersal mechanisms.
- Germination
  - **Germination Requirements.** The physical or chemical conditions needed to initiate seed germination.
- Seed Bank
  - **Soil Seed Bank Duration.** The time period over which seeds remain viable on the soil surface or in the subsurface.
- Adequate Abundance, Distribution, and Connectivity
  - **Viable Population Size.** Number of individuals needed to be considered a viable population.
  - **Occurrence Area.** Available metrics describing spatial areas of known occurrences.
  - **Patch Distance.** Minimum and maximum distances between occupied patches within a broader population area.
  - **Distribution Pattern.** The physical arrangement of populations and patches both locally and across a species' range.
- Suitable Habitat
  - **Geological Substrates.** The dominant geologic parent material(s) or formation(s) with which the species is typically associated.
  - **Soils.** The dominant soil texture, chemical composition, or other characteristics associated with the species' habitat.
  - **Moisture.** Degree of association with increased moisture levels (i.e., wetland obligates, occurrence in mesic habitats or areas of elevated soil moisture).

  - **Solar Exposure.** The slope, aspect, or other microhabitat characteristics that influence the relative degree of shading or exposure to sunlight.
  - **Associated Species Matrix.** Species commonly found in the immediate vicinity of occupied habitats for the species of interest.
  - **Disturbance Regime.** Fire, erosion, flooding, or other disturbances that the species has co-evolved with and/or known responses to disturbances that may be prevalent in the habitat area.
  - **Other.** Any additional relevant information not captured in the preceding categories.
- Suitable Climate
  - The precipitation and temperature ranges for most species were derived from PRISM (PRISM Climate Group n.d., unpaginated), using population locations as described in species descriptions. Using Google Earth, two points were selected within the species' described range of population locations and elevations: one at the most northern, highest elevation point and one at the most southern, lowest elevation point.
  - **Precipitation.** The range of average annual total precipitation values (for 2010–2020) in the areas where the species is found.
  - **Temperature.** The range of average minimum and maximum temperature values (for January 2010–December 2020) in the areas where the species is found. Average number of frost-free days is also included for some species.

A.2 Species Summaries

A.2.1 Sacramento Prickly Poppy (Argemone pinnatisecta)

Family: Papaveraceae

Federal status: Endangered, without designated critical habitat

A.2.1.1 General Summary

Sacramento prickly poppy (*Argemone pinnatisecta* (G.B. Ownbey) S.D. Cervantes & C.D. Bailey; synonym *Argemone pleiacantha* Greene ssp. *pinnatisecta* G.B. Ownbey) is an herbaceous perennial, 0.5–1.5 meters (m) (1.6–4.9 feet (ft)) tall, that has blue-green colored divided leaves with spine-tipped lobes extending almost to the midrib. It has large white flowers with six petals, numerous yellow stamens, and a purple stigma. It has white stem sap, which distinguishes it from the closely related *Argemone pleiacantha* ssp. *pleiacantha*, which has yellow-orange stem sap. Individuals generally live 7–9 years and die back to the root crown yearly. Sacramento prickly poppy is known only from the Sacramento Mountains in Otero County, New Mexico (NM), where it grows in loose, gravelly soils, often on disturbed sites such as canyon bottoms and slopes and along roadsides.

A.2.1.2 Threats

- Grazing: Young plants palatable to livestock, trampling.
- Flooding and erosion: Removes and buries individuals, drastically reshapes habitats, exacerbated by habitat loss and degradation.
- Road construction and maintenance: Herbicide use, mowing.
- Pipeline repair, replacement, and maintenance.
- Water extraction and diversion.
- Climate change.
- Low genetic diversity due to low population sizes.
- Plant pathogen *Alternaria* sp. affecting stressed plants.
- Young seedlings susceptible to desiccation in low moisture conditions.
- Off road vehicles.

A.2.1.3 Recovery and Conservation Needs

- Protect existing populations from anthropogenic (human-caused) threats.
- Maintain viable populations.
- Research germination and establishment requirements.

- Establish protocols for grow out and transplant processes.
- Research intraspecific genetic variation.

Table A.1. Species needs for Sacramento prickly poppy (*Argemone pinnatisecta*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Mostly outcrossing (cross-pollination), possibly selfing (self-pollinating) but yields small fruit and seed numbers, relying on outcrossing between other flowers on the same plant and other plants for high fruit and seed production.
Reproduction	Reproductive Season (Budding to Seeding)	Flowers bloom in the second year, beginning in May through summer, depending on available moisture.
Reproduction	Pollinators	Hymenoptera is likely the most highly abundant and effective pollinator group. Honeybees (*Apis mellifera*), bumble bees (*Bombus* spp.), carpenter bees (*Xylocopa californica arizonensis*), beetles (soldier beetles (Cantharidae) and lizard beetles (Languriidae)), flies (Diptera), and butterflies (Lepidoptera).
Dispersal	Distance	Very few seeds detected > 2.5 m (8.2 ft) from a maternal plant on flat ground and no seeds were detected >1.5 m (4.9 ft) downstream from a maternal plant in a dry wash. Seeds may move farther in a flash flood and via animal dispersal.
Germination	Germination Requirements	The thick seed coat requires cold stratification for germination, and germination is enhanced by scarification which may occur by tumbling among rocks or in the gizzards of birds. Seeds have been observed germinating in October into spring and August, episodically following periods of above average precipitation.
Seed Bank	Soil Seed Bank Duration	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Known only from the Sacramento Mountains in Otero County, NM; 1,280–2,164 m (4,200–7,100 ft).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Unknown; analysis of existing data needed.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Geographically restricted; clumpy distribution within range.
Suitable Habitat	Geological Substrates	Limestone, xeric uplands to mesic sites, arid canyon bottoms, grows in rock and gravel stream beds; vegetated bars of silt, gravel, and rock; cut slopes; and terraces above stream channels.
Suitable Habitat	Soils	Primarily limestone—sometimes sandstone and gypsum—derived, loose, and gravelly soils, where wet soil is well drained.
Suitable Habitat	Moisture	Germination and seedling survival require high moisture availability; plants are found where soil moisture is enhanced but not in wet stream banks, seeps, canyon bottoms, side drainages, along water pipelines, old fields, dry terraces, or above riparian areas.
Suitable Habitat	Solar Exposure	For plants in canyons, likely shaded part of the day, otherwise north facing slopes.
Suitable Habitat	Associated Species Matrix	Low elevation Chihuahuan Desert piñon-juniper scrublands and semi-desert grasslands to, at higher elevations in the Sacramento mountains, Great Basin ponderosa pine conifer woodland vegetation. *Aristida* spp., *Bouteloua curtipendula, Celtis laevigata* var. *reticulata, Chilopsis linearis, Fallugia paradoxa*, *Fraxinus velutina*, *Juniperus monosperma, Mahonia haematocarpa, Prosopis glandulosa, Quercus gambelii*, *Quercus grisea*, *Rhus trilobata, Vitis arizonica.*
Suitable Habitat	Disturbance Regime	Open and naturally or anthropogenically disturbed to relatively undisturbed.
Suitable Habitat	Other	The plant's wide range of habitat types has created uncertainty about its habitat requirements.

Need	Factor	Species Characteristics
Suitable Climate	Precipitation	Sacramento Mountains average 381 millimeters (mm) (15 inches (in)); most precipitation occurs during monsoon season, July to October. PRISM: 269–511 mm (10.6–20.1 in).
Suitable Climate	Temperature	Fluctuates widely but averages above 32°C (90°F) from mid-May through mid-October and gets as low as -9°C (16°F) during winter. PRISM: average (avg.) low = -0.9°C (30.3°F), avg. high = 29.1°C (84.4°F).

A.2.2 American Hart's-Tongue Fern (Asplenium scolopendrium var. americanum)

Family: Aspleniaceae

Federal status: Threatened, without designated critical habitat

A.2.2.1 General Summary

American Hart's-tongue fern (AHTF) is a rare, North American variety of a widespread species that is most abundant in Europe and Eurasia. The AHTF is a perennial, evergreen fern, closely associated with cool, moist refugia on dolomitic limestone bedrock under intact deciduous hardwood canopies with shallow soils and an open understory. However, in New Mexico, it occupies basaltic lava flows. The AHTF is distributed from central New York through south central Ontario and northern Michigan on glacially modified escarpments in areas of heavy lake-effect snowfall. Disjunct populations occur in sinkhole environments in Tennessee, Alabama, and New Mexico. The habitat of the disjunct population in Nuevo Leon is limestone ravines in pine-oak forests.

A.2.2.2 Threats

- Illegal collection, recreation, observer impacts.
- Any surface disturbance affecting moisture profiles of microhabitats.
- Threats that are specific to the NM occurrence:
    - Low genetic diversity from a limited population size.
    - More frequent and severe droughts and rising temperatures from climate change.
        - The AHTF is very susceptible to desiccation and temperature increases, especially when compared to *Asplenium scolopendrium* var. *scolopendrium* and similar ferns.
    - Invasive species.

A.2.2.3 Recovery and Conservation Needs

- Management of invasive species near AHTF habitat (especially European swallow-wort (*Vincetoxicum rossicum*)).
- Range-wide surveys at roughly 5-year intervals.
- Long-term monitoring of microclimatic sites in Tennessee and Alabama to determine possible future climate change impacts.

Table A.2. Species needs for American Hart's-tongue fern (*Asplenium scolopendrium* var. *americanum*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Gametophyte reproduction preferentially; almost completely relies on outcrossing. The level of intra- and inter-gametophytic selfing is unclear and possibly disputed but is likely low. Gametophytes can also reproduce asexually by fragmentation; this was also directly observed in the NM occurrence.
Reproduction	Reproductive Season (Budding to Seeding)	Spores are produced in June through September and disperse primarily in mid-August through mid-October. Mature fronds from previous growing seasons may release spores opportunistically throughout the year. Sporeling production starts soon after gametophyte maturation in early- to mid-summer and may continue through the end of the growing season (October/late fall).
Reproduction	Pollinators	N/A
Dispersal	Mechanism/ Agents	Spore dispersal hasn't been explicitly studied but is assumed to be wind, in accordance with most terrestrial ferns. Gamete exchange requires a thin film of water or moisture on the gametophytes.
Dispersal	Distance	Not specifically studied for the AHTF. However, USFWS considers 20 m (66 ft) to be the spore dispersal and population radius.
Germination	Germination Requirements	Gametophytes germinate in March–June, sporelings in June–October.
Seed Bank	Soil Seed Bank Duration	Unknown, germination from persistent spore banks is possible.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Populations below 100 are likely to decline to a point where extirpation would be likely from stochastic environmental fluctuations. Populations below 400 but above 100 are likely to decline to a point where full recovery is slow/unlikely. Populations above 400 are most resilient.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	The NM occurrence inhabits a roughly spherical lava tube ~4 m in diameter, and the occupied area is about 9–12 m^2 (100–129 ft^2). Known only from El Malpais National Monument, Cibola County in NM.
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Unknown; no other NM populations confirmed.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Small, disjunct populations known in NM, Alabama, Tennessee, and Nuevo León, Mexico; primarily occurs in Michigan, New York, and Ontario, Canada where populations are small and isolated, as evidenced by low gene flow and signs of inbreeding.
Suitable Habitat	Geological Substrates	Usually dolomitic limestone, although the NM occurrence occupies a basaltic lava field (the McCarty's lava flow of the Zuni-Bandera volcanic field). The cave in which AHTF was found had whitish mineral deposits that could be gypsum but weren't analyzed.
Suitable Habitat	Soils	NM plants were found growing either in thin soil or directly in contact with basalt. The specific soil texture/composition has not been studied.
Suitable Habitat	Moisture	Usually found in the presence of moisture, although precise levels are not known. The NM occurrence was described as living in a "high humidity" microclimate. The New York populations were growing in a mean soil moisture of 164 ± 67 %.
Suitable Habitat	Solar Exposure	Generally, prefers lower light intensity, likely to avoid desiccation of sporelings and gametophytes.

Need	Factor	Species Characteristics
Suitable Habitat	Associated Species Matrix	The general area surrounding the AHTF habitat was inhabited by *Opuntia phaeacantha*, *O. polyacantha*, *Pinus edulis*, *Cylindropuntia imbricata*, *Fallugia paradoxa*, *Atriplex canescens, Yucca baccata, Heterotheca villosa,* and other xerophytic species. In cave microclimates similar to the one in which the AHTF was found: *Asplenium trichomanes* subsp. *trichomanes* and the mosses *Sanionia uncinata*, *Eurhynchium pulchellum*, *Paraleucobryum enerve*, *Platydictya jungermannioides*, and *Tortella tortuosa*.
Suitable Habitat	Disturbance Regime	No research found indicating that the AHTF evolved with disturbance. Disturbance may allow weedy natives/invasives to spread and compete with the fern.
Suitable Habitat	Other	N/A
Suitable Climate	Precipitation	Highly variable. Annual precipitation at a central New York site was 977 mm (38.5 in). In contrast, annual precipitation at El Malpais, the location of the NM population, was 264 mm (10.4 in).
Suitable Climate	Temperature	Lacks tolerance for temperatures above 20°C (68°F) and struggles with below freezing temperatures without insulation (from cave, snowpack, etc.). The NM occurrence was found in a cave buffered from external conditions: it was ~3.3°C in the cave while it was -4°C outside.

A.2.3 Mancos Milkvetch (Astragalus humillimus)

Family: Fabaceae

Federal status: Endangered, without designated critical habitat

A.2.3.1 General Summary

Mancos milkvetch (*Astragalus humillimus* A. Gray ex Brand; hereafter referred to as milkvetch) is a tufted, sprawling perennial forb with spiny leaf stalks, lavender to purplish flowers, and egg-shaped fruit pods containing 4–9 seeds. It is narrowly endemic to the Four Corners region in New Mexico (San Juan County) and Colorado (Montezuma County), where it occurs on rimrock/sandstone outcrops in microhabitats where soil and moisture can collect, typically in cracks or fissures or in small depressions (tinajas) in the bedrock.

A.2.3.2 Threats

- Surface disturbance from oil and gas development, road construction, transmission line construction and maintenance, illegal wood cutting, and off-road vehicles.
- Changes to soil chemistry caused by fallout from nearby coal-fired power plants.
- Small, restricted populations and risk of inbreeding depression.
- Climate change, especially drought and warmer temperatures.
- Pests, including spider mites and larval bruchine beetles, especially on plants weakened by drought.
- Insecticides impacting important pollinators.
- Low soil mycorrhizal abundance, limiting germination and growth.

A.2.3.3 Recovery and Conservation Needs

- Ex-situ seed banking and population augmentation.
- Genetic research evaluating population genetic diversity (for seed banking and population augmentation efforts).
- Increased regulations for oil and gas activities.
- Limit off-road vehicle (ORV) activity and wood cutting.
- Long-term monitoring.

Table A.3. Species needs for Mancos milkvetch (*Astragalus humillimus*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Outcrossing and selfing, pollinators required for both; outcrossing is believed to be more successful than selfing. Low numbers of seed pods per plant and low seed fill per pod have been observed, suggesting insufficient pollination and/or inbreeding depression leading to embryo abortion.
Reproduction	Reproductive Season (Budding to Seeding)	Blooms late April and early May (earlier than many surrounding plants, possibly influencing pollinator activity), fruits ripen by early June.
Reproduction	Pollinators	Bees (*Osmia titusi* and *O. sculleni*), honeybees, and butterflies (including *Vanessa cardui*) observed resting on fragrant plants.
Dispersal	Mechanism/ Agents	Research needed; likely similar to other rare *Astragalus* spp.: limited-distance dispersal by surface run-off.
Dispersal	Distance	Unknown; research needed.
Germination	Germination Requirements	Seeds likely germinate in March and rely on sufficient spring rainfall to establish until monsoons in July. Seedlings mature after two growing seasons and flower in the third and fourth year. Populations mostly composed of small seedlings with relatively few adults suggesting allocation towards reproductive effort and high rates of seedling mortality.
Seed Bank	Soil Seed Bank Duration	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	48 x 24 kilometers (km) (30 x 15 miles (mi)), avg. 1,854 m (6,083 ft) elevation.
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Unknown; analysis of existing data required.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Narrow endemic; widely scattered subpopulations within range.
Suitable Habitat	Geological Substrates	Restricted to large, sloping sheets of whitish-tan, exfoliating, Mesa Verde series Cretaceous sandstone ledges and mesa tops within a 10-mile-wide section of a narrow band of Mesozoic sandstone derived from the Hogback formation.
Suitable Habitat	Soils	Sandy soils that accumulate in cracks or shallow bowl-like depressions (tinajas). Plants fare better in deep cracks than in narrow cracks or tinajas due to increased water holding capacity.
Suitable Habitat	Moisture	Plants are very sensitive to high and low moisture.
Suitable Habitat	Solar Exposure	Various aspects; flat or gentle slopes.
Suitable Habitat	Associated Species Matrix	Sparse piñon-juniper woodland and desert scrub communities: *Brickellia microphylla* var. *scabra, Castilleja chromosa, Cercocarpus intricatus, Cercocarpus montanus, Eriocoma hymenoides, Eriogonum alatum, E. ovalifolium, Fraxinus anomala, Heterotheca villosa, Ipomopsis roseata, Oreocarya fulvocanescens*, and *Physaria fendleri.* Broader scale associates also include *Artemisia tridentata, Gutierrezia sarothrae*, and *Yucca angustissima.*
Suitable Habitat	Disturbance Regime	Highly sensitive to disturbance.
Suitable Habitat	Other	Difficult to establish from seed and keep in cultivation due to specific watering preferences. Likely symbiotic with mycorrhizal fungi and *Rhizobium* spp. (like most *Astragalus* species).
Suitable Climate	Precipitation	203–229 mm (8–9 in) annually. PRISM: 305 mm (12 in).
Suitable Climate	Temperature	150 days without a killing frost. PRISM: avg. low = -4.4°C (24.1°F), avg. high = 24.7°C (76.5°F).

A.2.4 Sacramento Mountains Thistle (Cirsium vinaceum)

Family: Asteraceae

Federal status: Threatened, without designated critical habitat

A.2.4.1 General Summary

Sacramento Mountains thistle (*Cirsium vinaceum* (Wooton & Standley) Wooton & Standley) is a rhizomatous biennial species with 1–2 m tall branching stems arising from a robust basal rosette with green, glabrous leaves divided nearly to the midrib and divisions tipped with slender spines. Flower heads are solitary at the end of stem branches and are characterized by rose-purple disc flowers and deep red-purple involucral bracts that are reflexed and tipped with short spines. This thistle is known from six canyons at the southern end of the Sacramento Mountains in Otero County, New Mexico, where it is found along streams or forest margins in wet soils associated with springs and seeps. It is typically associated with travertine deposits, due to high calcium carbonate concentrations. The species can grow abundantly in dense, pure stands within its limited range.

A.2.4.2 Threats

- Livestock grazing.
- Introduced non-native plant species encroachment and competition.
- Seed predation and stem damage by native and introduced insects and fungi, including biocontrol agents.
- Herbicide application.
- Water diversions.
- Water flow alterations.
- Climate change; drought and warmer temperatures reduce water availability.

A.2.4.3 Recovery and Conservation Needs

- Acquire water rights for at least 30% of the occupied travertine springs.
- Create habitat management plans that alleviate threats in at least 70% of the occupied habitat.
- Establish a 10-year monitoring and research plan to assess the effectiveness of restoration.

Table A.4. Species needs for Sacramento Mountains thistle (*Cirsium vinaceum*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Mostly outcrossing but does exhibit partial self-compatibility and is capable of rhizomatous asexual reproduction.
Reproduction	Reproductive Season (Budding to Seeding)	Flowering starts in late-June, and plants flower and set seed into early-September. Plants die after reproducing, and seeds disperse autumn through winter.
Reproduction	Pollinators	Hawk moths (Sphingidae family), butterflies, 28 species of bees, and 5 species of hummingbirds.
Dispersal	Mechanism/ Agents	Strong evidence for aquatic dispersal; seed has pappus aiding in wind dispersal.
Dispersal	Distance	Estimated up to 0.8 km (0.5 mi).
Germination	Germination Requirements	Research needed; unable to germinate below dense teasel canopy.
Seed Bank	Soil Seed Bank Duration	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; Research needed.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	48 x 24 km (30 x 15 mi).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Occupied sites are typically within 100 m (328 ft) of each other.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Narrow endemic with spotty distribution within a limited range. Patches range in area from very small to up to 2 hectares (ha) (5 acres (ac)). Total distribution area estimated at 28ha (70 ac).
Suitable Habitat	Geological Substrates	Limestone.
Suitable Habitat	Soils	Wet, travertine deposits with high calcium carbonate content.
Suitable Habitat	Moisture	Saturated soils at travertine springs, seeps, and streams, with either surface or subsurface water flow.
Suitable Habitat	Solar Exposure	Meadows and partially shaded forests, flat or gentle slopes.

Need	Factor	Species Characteristics
Suitable Habitat	Associated Species Matrix	Mixed conifer forests and open valleys: *Apocynum cannabinum, Baccharis salicina, Distichlis spicata, Juncus balticus* ssp. *littoralis, Phragmites australis, Pinus ponderosa*, *Pseudotsuga menziesii*, *Quercus gambelii*, *Robinia neomexicana*, *Schoenoplectus americanus, Sorghastrum nutans,* and *Sporobolus airoides.*
Suitable Habitat	Disturbance Regime	Streamside habitats subject to flooding.
Suitable Habitat	Other	Low tolerance to freezing, high seedling mortality.
Suitable Climate	Precipitation	PRISM: 455–620 mm (17.9–24.4 in).
Suitable Climate	Temperature	PRISM: avg. low = -2.2°C (28°F), avg. high = 22.1°C (71.7°F).

A.2.5 Wright's Marsh Thistle (Cirsium wrightii)

Family: Asteraceae

Federal status: Threatened, with designated critical habitat

A.2.5.1 General Summary

Wright's Marsh Thistle (*Cirsium wrightii* A. Gray) is an herbaceous biennial with a basal rosette; somewhat succulent, long, sinuate or pinnatifid leaves; and flowering stems that can grow up to 2.5 m (8.2 ft) tall. The eastern populations have pink flowers and dark green foliage while the western and southern populations have white or pale pink flowers and pale green foliage. This wetland obligate is known from eight localities in New Mexico (Socorro, Otero, Guadalupe, Eddy, and Chaves counties), where it grows in wet, alkaline springs, seeps, and marshes.

A.2.5.2 Threats

- Livestock grazing.
- Invasive plant species encroachment.
- Seed predation and stem damage by native and introduced insects.
  - Primary insect predator is the native Tephritid fly (*Paracantha gentilis*).
- Herbicide application.
- Decreased water availability.
  - Draining and development of wetlands, ground and surface water usage, drought, climate change, etc.
- Oil and gas and mineral development.
- Wildfires.

A.2.5.3 Recovery and Conservation Needs

- Maintain and protect the existing populations and their habitats to ensure long-term viability of the species and maintain ecological and genetic diversity.
- Continue inventorying existing populations to determine population trends and identify areas to direct conservation and restoration efforts.
- Research the effects that current levels of water withdrawals and climate change will have on the species and its habitat.
- Develop seed bank and propagation strategies to ensure population diversity is protected against stochastic events and to provide a foundation for future population augmentation and reintroduction.

- Develop a habitat condition assessment framework to determine elements that are important or essential to maintenance and recruitment of the species within existing populations.
- Survey areas of suitable habitat within the historical range to find new population sources or identify areas where suitable habitat may exist or could be restored to support reintroduced populations. Utilize the habitat assessment framework to prioritize areas for various management actions such as protection, restoration, or reintroduction.
- Identify and implement management actions that would minimize, neutralize, or protect Wright's marsh thistle from known threats.

Table A.5. Species needs for Wright's marsh thistle (*Cirsium wrightii*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Outcrossing, does not reproduce asexually.
Reproduction	Reproductive Season (Budding to Seeding)	Remains a rosette for one to two years before flowering, dies after reproducing. Requires direct sunlight to produce seeds. Flowers August-October.
Reproduction	Pollinators	Primarily bees (*Bombus* spp.), also black swallowtails (*Papilio polyxenes*), green June beetles (*Cotinis nitida*), oblique syrphid flies (*Allograpta obliqua*), other insect pollinators, and hummingbirds.
Dispersal	Mechanism/ Agents	Wind, water, birds, mammals.
Dispersal	Distance	Unknown; relevance depends on extent of suitable wetland habitat within which seeds could disperse and successfully germinate and establish.
Germination	Germination Requirements	Research needed; assumed to require sunlight/well-lit conditions to germinate.
Seed Bank	Soil Seed Bank Duration	Understudied but likely not persistent due to high moisture sites and seed predation.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Occupied areas range from 0.01 to ~16.07 ha (0.03 to ~39.7 ac).

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Patches at some sites are up to 1 km (0.6 mi) from nearest neighbors, but intervening habitat may or may not be suitable. Populations are entirely isolated, separated from other occurrences by 121–346 km (75–215 mi).
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Scattered occurrences; subpopulations isolated and widely dispersed.
Suitable Habitat	Geological Substrates	Calcareous formations, including the Yeso and San Andres formations.
Suitable Habitat	Soils	Wet, alkaline soils.
Suitable Habitat	Moisture	Springs, seeps, marshy edges of streams and ponds, wet/saturated.
Suitable Habitat	Solar Exposure	Full sun is likely optimal; grows in open areas.
Suitable Habitat	Associated Species Matrix	Wetlands: *Apocynum cannabinum, Baccharis salicina*, *Distichlis spicata, Flaveria chlorifolia, balticus* ssp. *littoralis, Limonium limbatum, Muhlenbergia asperifolia, Phragmites australis, Schoenoplectus americanus, Solidago canadensis, Sorghastrum nutans, Sporobolus airoides, Helianthus paradoxus,* and *Spiranthes magnicamporum.*
Suitable Habitat	Disturbance Regime	May be disturbance tolerant but primarily grows in undisturbed areas.
Suitable Habitat	Other	May hybridize with other thistles, but hybrid offspring are uncommon; has hybridized with *C. vinaceum* and *C. texanum*.
Suitable Climate	Precipitation	PRISM: 335–615 mm (13.2–24.2 in).
Suitable Climate	Temperature	PRISM: avg. low = -2.2°C (28°F), avg. high = 30.2°C (86.3°F).

A.2.6 Lee Pincushion Cactus (Coryphantha sneedii var. leei)

Family: Cactaceae

Federal status: Threatened, without designated critical habitat

A.2.6.1 General Summary

Both Sneed pincushion cactus (*Coryphantha sneedii* (Britton & Rose) A. Berger var. *sneedii*) and Lee pincushion cactus (Lee's; *Coryphantha sneedii* (Britton & Rose) A. Berger var. *leei* (Rose ex Boed.) L.D. Benson) are many-branched, forming tight clumps of up to 100 or more cylindrical to spherical stems with 3mm long tubercles. Tepals are pale yellowish to pinkish or nearly white, usually with darker midribs. On both varieties, flowers do not open widely and only stay open for a few hours, mid-day. There are 6–17 central spines and 35–90 radial spines per areole. Lee's has spines that are appressed to the stems while Sneed pincushion cactus has variously oriented spines that protrude from the stems. Lee's occurs in southeastern New Mexico in the Guadalupe Mountains and adjacent foothills.

A.2.6.2 Threats

- Construction, maintenance, and use of recreation attractant features (such as roads, trails, picnic areas, and campsites), range improvements (such as fences, water lines, tanks, troughs, feeders, and corrals), and other infrastructure (such as pipelines, transmission lines, facility pads, etc.).
- Ungulate trampling.
- Fire suppression and uncharacteristic wildfire.
- Pesticide applications.
- Climate change (warmer temperatures, droughts, etc. and potential for increases in wildfires and insect and mammal herbivory).
- Possibly, hybridization.
- Possibly, decreases in air quality.
- Overutilization via illegal collection for recreational or spiritual purposes is a potential emerging future risk.

A.2.6.3 Recovery and Conservation Needs

- Resolve the taxonomic identity of Sneed's-form plants range-wide and in the Sneed's-form core population area. Sneed's-form plants (previously believed to be Sneed pincushion cactus occurrences within the Guadalupe Mountains) have traits intermediate between classic Lee's traits (i.e., appressed spines) and *Escorbaria guadalupensis*.

- Survey suitable habitats as predicted by probabilistic models for the presence/absence and extent of Lee's occurrences, starting with the Sargent Canyon occurrence area. Consider evaluating the feasibility of using aerially assisted remote sensing and artificial intelligence assisted object detection techniques to identify potentially occupied areas for on-the-ground presence/absence survey efforts.
- Map the bounds of Lee's occurrences within occupied areas, using standardized and repeatable methods.
- Install randomly or systematically located demographic and density monitoring plots throughout the species' range. Determine the plot specifications and sample sizes needed to achieve the desired statistical power experimentally.
- Assess the probability of wildfire exposure in occurrence areas.
- Assess microclimate refugia in and adjacent to occurrence areas.
- Assess Lee's resiliency to, and capacity to adapt to, projected future climate changes. If resiliency and adaptive capacity are low, identify future suitable habitat areas using probabilistic models that incorporate the range of available future climate scenarios and time periods.
- Collect seeds along >50 maternal lines per occurrence area for ex-situ, long-term conservation storage. Consider what germplasm may be needed for successful reintroductions when planning collections (Maschinski et al. 2012, entire).
- Finalize protections for Lee's occupied and adjacent and intervening habitats, including future habitats, via special designations and associated mineral withdrawals and management prescriptions for the purpose of conserving Lee's.

Table A.6. Species needs for Lee pincushion cactus (*Coryphantha sneedii* var. *leei*). Guadalupensis = *Escobaria guadalupensis*.

Need	Factor	Species Characteristics
Reproduction	Breeding System	Two stem types: one type facilitates asexual vegetative reproduction (~10 percent of all stems) while the other produces flowers; it's unknown if flowers are capable of selfing. Plants are usually clustered, supporting high pollination rates. Plants become sexually reproductive at 3–4 years of age.
Reproduction	Reproductive Season (budding to seeding)	Flowers bud in late March or early April and mature quickly, blooming within 2–4 weeks in favorable weather: mid- to late April through early to mid-May. Flowers open mid-day (~10:00 A.M. to 4:00 P.M) and last 2–4 days each. Fruits ripen 4–5 months after anthesis: August–October/November.

Need	Factor	Species Characteristics
Reproduction	Pollinators	Understudied; members of the Halictid family (sweat bees) observed.
Dispersal	Mechanism/Agents	Fruits eaten by insects or rodents which likely scatter some seeds; birds also observed feeding on fruits. If not eaten, seeds dispersed by wind and rain.
Dispersal	Distance	Unknown; research needed
Germination	Germination Requirements	Seeds have no special requirements for breaking dormancy. Germination is enhanced when seeds fall into a layer of fine limestone pebbles overlying a flat, impermeable (moisture collecting), bedrock slab. Seeds likely germinate with adequate moisture, light, and warmth. Seedlings are tiny and remain hidden under groundcover for a few months to a year before becoming detectable at the soil surface.
Seed Bank	Soil seed bank duration	Likely has a robust seed bank with seeds maintaining viability for up to 10 years in the wild.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	One to two known core population and representation areas, depending on the taxonomic identify of Lee's Sneed's-form plants beyond the geographic range of plants exhibiting classic Lee's morphology. Relatively continuous known range (excluding the disjunct Sargent Canyon occurrence, which is known from a single individual) extends approximately 30 kilometers (km) (19 miles (mi)) southwest to northeast (including Sneed's-form individuals within putative Guadalupensis occurrence areas) or approximately 15 km (9 mi) southwest to northeast (excluding those populations). The disjunct Sargent Canyon individual is approximately 58 km (36 mi) northwest of the north-most Lee's in the Serpentine Bends area. Historical abundance estimates of Lee's within the Guadalupe Mountains range from 1,000 to "10,000 or fewer" plants; to date, approximately 1,450 Lee's and/or Sneed's-form plants have been counted (including potential duplicate counts) since 1977 in the Guadalupe Mountains and adjacent foothills. 1,230–1,800 m (4,030–5,900 ft).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Analysis of occurrence data needed.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Lee's is known to occur within 10–15 canyons or canyon complexes, depending on the taxonomic identity of Sneed's-form plants within Guadalupensis occurrence areas. Within these canyons, plant distribution ranges from few to several scattered and/or clustered plants.
Suitable Habitat	Geological Substrates	Limestone; known from the Capitan, Yates and Tansill, Seven Rivers, San Andres, and Artesia Group formations and, perhaps also, the Queen and Grayburg formation.
Suitable Habitat	Soils	Limestone rock land, rock outcrops, and shallow, gravelly loam soils.
Suitable Habitat	Moisture	Winter and spring moisture are important for bud set.

Need	Factor	Species Characteristics
Suitable Habitat	Solar Exposure	Full sun to partial shade. Prefers northern aspects (cooler and moister soils).
Suitable Habitat	Associated Species Matrix	Semi-desert grassland/Chihuahuan desert scrub: *Acacia* sp., *Agave lechuguilla, Aloysia wrightii, Arbutus xalapensis, Aristida purpurea, Artemisia ludoviciana, Berberis trifoliolata, Bernardia myricifolia, Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua gracilis, Brickellia laciniata, Castilleja integra, Ceanothus pauciflorus, Cercocarpus montanus, Choisya dumosa, Chrysactinia mexicana, Croton* sp., *Dalea bicolor, Dalea formosa, Dasylirion leiophyllum, Dasylirion wheeleri, Dermatophyllum secundiflorum, Echinocereus coccineus, Epithelantha micromeris, Eragrostis intermedia, Erigeron flagellaris, Eriogonum* sp., *Fendlera rupicola, Fouquierra splendens, Galium microphyllum, Gutierrezia sarothrae, Gymnosperma glutinosum, Hesperostipa* sp., *Juniperus monosperma, Melmapodium leucanthum, Menodora* sp., *Mimosa biuncifera, Mirabilis* sp., *Muhlenbergia rigida, Muhlenbergia setifolia, Nama xylopoda, Nolina microcarpa, Oenothera* sp., *Opuntia engelmannii, Opuntia phaeacantha, Pelecyphora tuberculosa, Pelecyphora vivipara, Penstemon cardinaIis, Perityle quinqueflora, Petrophyton caespitosum, Philadelphus mearnsii, Quercus grisea, Quercus pungens, Ruellia parryi, Salvia summa, Senegalia roemeriana, Senna* sp., *Streptanthys sparsiflorus, Tetraneuris* sp., *Thymophylla pentachaeta, Tradescantia wrightii, Tridens muticus, Vachellia vernicosa, Yucca* sp., *Juniperus pinchotii,* and the moss *Hemionitis cochisensis.*
Suitable Habitat	Disturbance Regime	Fire-dependent habitat type, but plants sensitive to uncharacteristic wildfire.
Suitable Habitat	Other	N/A
Suitable Climate	Precipitation	Carlsbad Caverns NP (Lee): avg. 373 mm (14.7 in). annually. PRISM: avg. 356–404 mm (14–15.9 in).
Suitable Climate	Temperature	PRISM: avg. low = 3.1°C (37.6°F), avg. high = 29.7°C (85.4°F).

A.2.7 Sneed Pincushion Cactus (Coryphantha sneedii var. sneedii)

Family: Cactaceae

Federal status: Endangered, without designated critical habitat

A.2.7.1 General Summary

Both Sneed pincushion cactus (Sneed's; *Coryphantha sneedii* (Britton & Rose) A. Berger var. *sneedii*) and Lee pincushion cactus (*Coryphantha sneedii* (Britton & Rose) A. Berger var. *leei* (Rose ex Boed.) L.D. Benson) are many-branched, forming tight clumps of up to 100 or more cylindrical to spherical stems with 3mm long tubercles. Tepals are pale yellowish to pinkish or nearly white, usually with darker midribs. On both varieties, flowers do not open widely and only stay open for a few hours, mid-day. There are 6–17 central spines and 35–90 radial spines per areole. Lee pincushion cactus has spines that are appressed to the stems while Sneed's has variously oriented spines that protrude from the stems. Sneed's occurs in west Texas and southern New Mexico in the Franklin Mountains and, possibly, the Organ Mountains and peaks between these two ranges.

A.2.7.2 Threats

- Private land use and residential, commercial, and transportation system development.
- Construction, maintenance, and use of recreation attractant features (such as roads, trails, picnic areas, and campsites), range improvements (such as fences, water lines, tanks, troughs, feeders, and corrals), and other infrastructure (such as pipelines, transmission lines, facility pads, etc.).
- Mineral materials development.
- Ungulate trampling.
- Fire suppression and uncharacteristic wildfire.
- Pesticide applications.
- Climate change (warmer temperatures, droughts, etc. and potential for increases in wildfires and insect and mammal herbivory).
- Possibly, military artillery impact.
- Overutilization via illegal collection for recreational or spiritual purposes is a potential emerging future risk.

A.2.7.3 Recovery and Conservation Needs

- Resolve the taxonomic identity of "Sneed's" plants (plants that look like Sneed's but may be taxonomically distinct) in the Webb Gap, Bishop's Cap, and Rattlesnake Ridge populations.

- Create a digitized map of outcrops of the geologic layers associated with Sneed's.
- Once mapped, survey suitable geologic layer outcrops for the presence/absence and extent of Sneed's occurrences.
- Map the bounds of Sneed's occurrences within occupied areas, using standardized and repeatable methods.
- Install randomly or systematically located demographic and density monitoring plots throughout the species' range. Determine the plot specifications and sample sizes needed to achieve the desired statistical power experimentally.
- Assess Sneed's resiliency to, and capacity to adapt to, projected future climate changes.
- Collect seeds along >50 maternal lines per site for ex-situ, long-term conservation storage. Consider what germplasm may be needed for successful reintroductions when planning collections (Maschinski et al. 2012, entire).
- Finalize protections for Sneed's occupied and adjacent and intervening habitats, including future habitats, via special designations and associated mineral withdrawals and management prescriptions for the purpose of conserving Sneed's.

Table A.7. Species needs for Sneed pincushion cactus (*Coryphantha sneedii* var. *sneedii*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Two stem types: one type facilitates asexual vegetative reproduction (~10 percent of all stems) while the other produces flowers; it's unknown if flowers are capable of selfing. Plants are usually clustered, supporting high pollination rates. Plants become sexually reproductive at 3–4 years of age.
Reproduction	Reproductive Season (budding to seeding)	Flowers late March through April, sometimes followed by an opportunistic second blooming following summer rains in July–August. Flowers open mid-day (~10:00 A.M. to 4:00 P.M), and last 2–4 days each. Fruits ripen 3–4 (-5) months after anthesis: August to November.
Reproduction	Pollinators	Understudied; members of the Halictid family (sweat bees) observed.
Dispersal	Mechanism/Agents	Fruits eaten by insects or rodents which likely scatter some seeds; birds also observed feeding on fruits. If not eaten, seeds dispersed by wind and rain.
Dispersal	Distance	Unknown; research needed

Need	Factor	Species Characteristics
Germination	Germination Requirements	Seeds have no special requirements for breaking dormancy. Germination is enhanced when seeds fall into a layer of fine limestone pebbles overlying a flat, impermeable (moisture collecting), bedrock slab. Seeds likely germinate with adequate moisture, light, and warmth. Seedlings are tiny and remain hidden under groundcover for a few months to a year before becoming detectable at the soil surface.
Seed Bank	Soil seed bank duration	Likely has a robust seed bank, with seed maintaining viability for up to 10 years in the wild.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Sneed's occurs in 2–5 populations, depending on the taxonomic identity of "Sneed's" plants in the Webb Gap, Bishop's Cap, and Rattlesnake Ridge populations. Sneed's range extends either approximately 40 km (25 mi) or 19 km (12 mi) north/south, depending on the taxonomic identity of "Sneed's" plants in those populations. Sneed's historically consisted of approximately 1,953–2,653 (2,303) or 8,339–27,896 (18,118) individuals—depending on the taxonomic identity of "Sneed's" plants in those populations—based on abundance estimates, abundance observations, and plants counts made between 1975 and 2012. 1,300–2,380 m (4,260–7,810 ft).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Analysis of occurrence data needed.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Sneed's currently occupies 2–5, geographically isolated and genetically distinct representation areas, depending on phylogenetic analysis results. Within these, there are 3–4 sites documented in the South Franklin Mountains, four sites documented in the North Franklin Mountains, one site documented at Webb Gap, three sites documented at Bishop's Cap, and one site documented at Rattlesnake Ridge. Known sites typically contain hundreds to thousands of loosely to tightly clustered plants.
Suitable Habitat	Geological Substrates	Always found on or within a few meters of Silurian-Ordovician-Cambrian limestone; known only from Fusselman dolomite and associated Montoya Group limestone and sandstone.
Suitable Habitat	Soils	Limestone rock land, rock outcrops, and shallow, gravelly loam soils.
Suitable Habitat	Moisture	Winter and spring moisture are important for bud set.
Suitable Habitat	Solar Exposure	Full sun to partial shade.

Need	Factor	Species Characteristics
Suitable Habitat	Associated Species Matrix	Usually in semi-desert grasslands, with *Agave lecheguiila* and *Pelecyphora tuberculosa*; at higher altitudes, it occupies ledges in association with *Muhlenbergia pauciflora*, *Fendlera rupicola*, and *Quercus benthamii*. *Rhus virens, Ferocactus uncinatus, Larrea tridentata, Larrea divaricata, Prosopis glandulosa, Flourensia cernua, Viguiera stenoloba, Parthenium incanum, Alyosia wrightii, Sidneya tenuifolia, Brickellia baccharidea, Artemisia ludoviciana, Gymnosperma glutinosum, Krameria erecta, Ephedra aspera, Fouquierra splendens, Yucca faxoniana, Yucca treculeana, Dasylirion wheeleri, Agave lechuguilla, Opuntia engelmannii, Pelecyphora chihuahuensis, Pelecyphora tuberculosa, Echinocactus horizonthalonius, Echinocereus fendleri, Echinocereus dasyacanthus, Echinocereus gurneyi, Epithelantha micromeris, Ferocactus uncinatus, Galium* sp., *Hebecarpa macradenia, Hemionitis cochisensis, Linum vernale, Melampodium leucanthum, Oenothera brachycarpa, Physaria fendleri, Picradeniopsis absinthifolia, Thymophylla pentachaeta, Tiquilia greggii, Bouteloua* sp., and various other grasses.
Suitable Habitat	Disturbance Regime	Fire-dependent habitat type, but species' response to fire effects unknown.
Suitable Habitat	Other	N/A
Suitable Climate	Precipitation	Avg. 300 mm (11.8 in) annually. PRISM Sneed range: avg. 244–353 mm (9.6–13.9 in).
Suitable Climate	Temperature	PRISM: avg. low = 3.2°C (37.8°F), avg. high = 30.2°C (86.4°F).

A.2.8 Kuenzler Hedgehog Cactus (Echinocereus fendleri var. kuenzleri)

Family: Cactaceae

Federal status: Threatened, without designated critical habitat

A.2.8.1 General Summary

Kuenzler's hedgehog cactus (*Echinocereus fendleri* (Engelmann) Engelmann ex Rmper var. *kuenzleri* (Castetter, Pierce, & Schwerin) L. Benson) has single or several (clustered), short stems with very few, very thick spines (typically without central spines) and relatively few ribs. It is known from 11 population centers in New Mexico (Otero, Lincoln, Eddy, and Chaves counties), where it grows in cracks in limestone outcrops or shallow soils. It has magenta flowers and bright red fruits.

A.2.8.2 Threats

- Altered fire regimes.
- Drought and climate change.
- Intense grazing pressure and/or concentrated livestock use.
- Herbivory by rodents and frugivory by rodents, grasshoppers, and other insects.
- Parasitic insects.
- Genetic diversity loss through small population sizes and lack of connectivity.
- Juniper encroachment.
- Uncharacteristic, high-intensity wildfire.

A.2.8.3 Recovery and Conservation Needs

- Remove potential and existing threats.
  - Protect habitat on private and public lands.
  - Reduce illegal collection through law enforcement and a trade management plan.
  - Develop public awareness.
- Establish a monitoring program to inform management decisions on sustaining and reestablishing healthy populations.
- Research and implement horticultural techniques for augmenting and introducing populations.

Table A.8. Species needs for Kuenzler hedgehog cactus (*Echinocereus fendleri* var. *kuenzleri*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Requires outcrossing, self-incompatible.
Reproduction	Reproductive Season (Budding to Seeding)	Becomes reproductive at 4–5 years of age. Flower buds form in April, and flowers bloom in May to early-June, depending on spring temperatures. Fruits ripen early July through August, averaging 3–6 fruits per plant, with each fruit containing as many as 1,050 seeds; seedlings sensitive to frost and drought.
Reproduction	Pollinators	Primarily bees: *Ashmeadiella opuntiae* (a cactus specialist bee, likely the most effective pollinator due to its morphology), *Lasioglossum semicaerulens*, *Diadasia australis*, *Chelostoma* sp., *Agapostemon angelicus/texanus*; also visited by ants, small beetles, and assassin bugs.
Dispersal	Mechanism/Agents	Dispersal occurs during September and October by rodents, wind, and water. Only seeds that are not consumed are likely to survive to germinate.
Dispersal	Distance	Unknown; research needed.
Germination	Germination Requirements	Requires 70°F and sufficient moisture for germination; seeds have over 90% viability and no known dormancy requirement.
Seed Bank	Soil Seed Bank Duration	Often at least 5 years.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	A population of under 200 individuals is considered to be in low (poor) condition; 200–500 plants is considered to be in moderate condition; and a population of >500 plants is considered optimal.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Four population centers: Northern Sacramento (highest number of plants 1,846+), Southern Sacramento (181+ plants), and Northern Guadalupe and Southern Guadalupe (322+ plants); total plant population estimated at 11,000–20,000 plants across 94,238 acres. 1,554–2,225 m (5,100–7,300 ft).

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Habitat with optimal conditions includes numerous colonies within an average distance to the nearest neighbor of less than 50 m (164 ft). Habitat with moderate conditions includes colonies within an average distance to the nearest neighbor between 50 to 200 m (164–656 ft). Habitat with low (poor) conditions includes colonies within an average distance to the nearest neighbor greater than 200 m (656 ft).
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Restricted patchy/random distribution; populations are isolated and only very rarely interbreed.
Suitable Habitat	Geological Substrates	Limestone; gentle slopes or benches.
Suitable Habitat	Soils	Cracks in limestone outcrops or shallow soils: sandy, silty, gravelly to rocky soils, allowing for fast soil drainage.
Suitable Habitat	Moisture	Low moisture requirements (CAM metabolism) but seedlings sensitive to drought.
Suitable Habitat	Solar Exposure	Various; south facing aspects preferred.
Suitable Habitat	Associated Species Matrix	Piñon-juniper woodlands; shrubby grassland to Juniper savanna; *Baccharis peteronioides, Bouteloua gracilis, Chaetopappa ericoides, Eragrostis intermedia, Eriogonum havardii, Garrya ovata* ssp. *goldmanii, Hedeoma costata* var. *pulchella, Juniperus deppeana, Juniperus monosperma, Lesquerella valida, Mammillaria heyderi, Oenothera suffrutescens, Pinus edulis, Salvia farinacea.*
Suitable Habitat	Disturbance Regime	Does not survive fire well.
Suitable Habitat	Other	Difficult to detect when not flowering; may live up to 40 years; likely experiences high seedling mortality.
Suitable Climate	Precipitation	Avg. 406mm (16in) annually. PRISM: 396–511 mm (15.6–20.1 in).
Suitable Climate	Temperature	Avg. 180 frost free days. PRISM: avg. low = -0.8°C (30.6°F), avg. high = 26.9°C (80.5°F).

A.2.9 Zuni Fleabane (Erigeron rhizomatus)

Family: Asteraceae

Federal status: Threatened, without designated critical habitat

A.2.9.1 General Summary

Zuni fleabane (*Erigeron rhizomatus* Cronquist) is an herbaceous perennial with creeping rhizomes. It grows in clumps up to 30cm in diameter. It has many (25–45) white (sometimes tinged blue-violet) ray flowers and yellow disk flowers. The plant is known from three widely scattered population centers (Datil/Sawtooth Mountains and Zuni Mountains in the U.S. and Chuska Mountains in Navajo Nation) in Catron, McKinley, and San Juan counties in New Mexico and Apache County in adjacent northeast Arizona. It grows in fine textured clay soils on sparsely vegetated slopes within piñon-juniper woodlands and transitional forests of ponderosa pine and Douglas-fir.

A.2.9.2 Threats

- Climate change (drought and warmer temperatures, wildfires).
- Mineral development (associated with uranium deposits).
- The small size and proximity to roads of the Zuni Mountains population makes it susceptible to stochastic events.

A.2.9.3 Recovery and Conservation Needs

- Protection from mineral development activity.
- Continued demographic monitoring.
- Implement a seed banking program (collecting, banking, and growing seed).
    - Verify that this species can be propagated from seed in captivity.

Table A.9. Species needs for Zuni fleabane (*Erigeron rhizomatus*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Sexual reproduction by seed may be infrequent; primarily reproduces asexually via rhizomes, creating a risk of inbreeding depression.
Reproduction	Reproductive Season (Budding to Seeding)	Flowers May–June.
Reproduction	Pollinators	No information; assumed to be generalist pollinators, such as bees, butterflies, and beetles.

Need	Factor	Species Characteristics
Dispersal	Mechanism/ Agents	Likely wind.
Dispersal	Distance	Unknown; research needed.
Germination	Germination Requirements	Propagation protocols for other *Erigeron* spp. in arid climates report little or no dormancy-breaking requirements. Unknown for this particular species.
Seed Bank	Soil Seed Bank Duration	Assuming low seed dormancy, soil seed bank duration may be short.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Occupied habitats range from less than 0.4ha (1 ac) to ~105.2 (260 ac) and from less than 10 to a few thousand plants. 2,225–2530 m (7,300–8,300 ft).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Unknown; analysis of existing data needed; ~64–113 km (40–70 mi) between metapopulations.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Isolated, widely dispersed subpopulations. Based on assumptions of pollinator ranges, the three metapopulations are assumed to be genetically isolated from one another while the sub-populations within each metapopulation are assumed to have genetic flow between them. Pollen exchange is assumed to happen within each metapopulation but not between.
Suitable Habitat	Geological Substrates	Shale outcrops of the Chinle (composed primarily of late-Tertiary fluvial and lacustrine deposits) and Baca formations; recently weathered detrital clay slopes or cliff benches with sandy soils, sometimes with a selenium odor.
Suitable Habitat	Soils	Primarily fine textured clay; also found in sandy soils.
Suitable Habitat	Moisture	No known moisture requirements.
Suitable Habitat	Solar Exposure	East, west, and north aspects but often does best on north aspects (doesn't occur on south aspects); 15–45° slopes.

Need	Factor	Species Characteristics
Suitable Habitat	Associated Species Matrix	*Astragalus flavus* (a primary indicator of selenium soils), *Astragalus albulus* (a secondary indicator of selenium soils, occurs at almost all sites in the Datil/Sawtooth Mountain metapopulation), *Amelanchier utahensis, Atriplex canescens, Brickellia brachyphylla, Brickellia oblongifolia* var. *linifolia, Cercocarpus montanus, Chaetopappa ericoides, Chrysothamnus depressus, Ericameria nauseosa, Eriocoma hymenoides, Eriogonum jamesii* var. *flavescens, Eurybia glauca, Forestiera pubescens, Fraxinus cuspidata, Gutierrezia sarothrae, Hymenopappus filifolius, Juniperus osteosperma, Lycium pallidum, Machaeranthera grindelioides* var. *grindelioides, Oxytropis lambertii, Pinus edulis, Pinus ponderosa, Pleuraphis jamesii, Poa fendleriana, Purshia stansburiana, Purshia tridentata, Quercus gambelii, Tetraneuris argentea, Yucca angustissima, Yucca baileyi,* and (in more shaded habitats) *Pseudotsuga menziesii* and *Solidago* sp.
Suitable Habitat	Disturbance Regime	Well-adapted to dry conditions but may be susceptible to extended dry periods paired with elevated temperatures.
Suitable Habitat	Other	Apparently unaffected by grazing, possibly due to its toxic selenium content.
Suitable Climate	Precipitation	Avg. 356–406 mm (14–16 in) annually. PRISM: avg. 310–472 mm (12.2–18.6 in).
Suitable Climate	Temperature	120-140 days without a killing frost. PRISM: avg. low = -4.4°C (24°F), avg. high = 21.3°C (70.3°F).

A.2.10 Gypsum Wild Buckwheat (Eriogonum gypsophilum)

Family: Polygonaceae

Federal status: Threatened, with designated critical habitat

A.2.10.1 General Summary

Gypsum wild buckwheat (*Eriogonum gypsophilum* Wooton &Standl.; hereafter referred to as Buckwheat) is a woody-stemmed perennial that grows in dense clumps, flowering at about 20 cm (8 in) high. It has relatively thick, dark-green leaves and yellow flowers. Buckwheat is known from four populations in Eddy County, New Mexico, where it is found growing in patches on gypsum outcrops within Chihuahuan desert scrub communities. Unsurveyed suitable habitat for Buckwheat extends south into Culberson County, Texas, and the existence of additional, undocumented populations in New Mexico and/or Texas is possible.

A.2.10.2 Threats

- Physical and chemical habitat alteration, such as soil compaction, exposure to toxic substances, and inadequate seasonally appropriate soil moisture.
    - Sources include seismic prospecting; solid mineral prospecting, exploration, and mining; fluid mineral prospecting, drilling, and production; infrastructure development; ranching; recreation; reclamation and restoration; and climate change.

A.2.10.3 Recovery & Conservation Needs

- Direct Conservation Actions
    - Maintain and extend barricades that block motor vehicle access to occupied areas. Close vehicle access to populations and to linear features intersecting populations.
    - Increase avoidance distances to 300 m for all potentially adverse land use or treatment activities. Maintain avoidance distances over time and across land jurisdictions.
    - Expand the Hay Hollow population to increase occupied extent and area. For example, establish subpopulations of plants from at least 50 Hay Hollow-sourced maternal lines in suitable soils on the adjacent escarpments north and south of the current Hay Hollow population.
    - Discover and/or introduce populations that increase gypsum wild buckwheat's range extent and diversity of associated vegetation types, geological units, and climate zones.

- Research and Monitoring
  - Expand long-term demographic monitoring across land jurisdictions. Maintain monitoring plots and continue demographic studies until the average transition matrix from 10–15 consecutive years of data demonstrates a stable or increasing population growth rate.
  - Identify and document gypsum wild buckwheat seed germination and seedling establishment requirements.
  - Identify and document specifications for suitable gypsum wild buckwheat soils (e.g., soil testing for percent gypsum, other nutrients, and soil microorganisms; soil depth probing; etc.).
  - Proactively model, survey, and map suitable gypsum wild buckwheat soils.
  - Identify and document techniques for restoring the gypsum wild buckwheat suitability of compacted, hypergypsic soils.
- Building Community Support
  - Install and maintain signs that support education about, and enforcement of, current and existing protective land use designations. Stay ahead of emerging adverse recreational use trends.
  - Recruit and retain botanical expertise amongst agency environmental review and project management staff.

Table A.10. Species needs for gypsum wild buckwheat (*Eriogonum gypsophilum*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Sexual reproduction via seed. Primarily outcrossing; likely partial self-compatibility with low seed set. Previously misreported to asexually reproduce by rhizomes, but *Eriongonum* spp. are tap-rooted, not rhizomatous.
Reproduction	Reproductive Season (Budding to Seeding)	Buds form in April, flowers primarily bloom in May, and seeds primarily mature in late June to early July.

Need	Factor	Species Characteristics
Reproduction	Pollinators	Mainly bees, but also flies, beetles, moths, and butterflies. Observed visitors include members of the order Lepidoptera (butterflies and moths); the families Bombyliidae (bee flies), Tachinidae (parasitic flies), Chloropidae (fruit flies), Lauxaniidae (flies), Buprestidae (jewel beetles), Melyridae (soft-wing flower beetles), Chalcididae (chalcid wasps), Eurytomidae (seed chalcid wasps), and Pteromalidae (parasitoid wasps) and the genera *Hedychridium, Paratiphia, Pompilini* (spider wasps), *Stenodynerys* (potter wasps), *Leptochilus* (potter wasps), *Diodontus, Belomicrus* (square-headed wasps), *Pluto* (aphid wasps), *Colletes* (plasterer bees), *Dialictus* (metallic sweat bees), *Perdita*, *Ashmeadiella* (solitary bees), *Anthophora* (digger bees), and *Centris* (fast-flying bees).
Dispersal	Mechanism/ Agents	Local dispersal primarily by wind, sheet run-off, ants, and small mammals; rare long-distance dispersal via birds or drainage flooding also possible.
Dispersal	Distance	Research needed; likely primarily local, short-distance dispersal.
Germination	Germination Requirements	Seeds require cold stratification and germinate whenever infrequent climatic episodes suitable for seed germination and seedling establishment occur during the growing season. Two consecutive years of adequate precipitation—one for flowering/seed set and one for germination—are required for successful recruitment.
Seed Bank	Soil Seed Bank Duration	Seed cohorts unlikely to produce a dormant fraction and, therefore, unlikely to remain viable in soil seed banks.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Provisional estimate of at least 806 genetically unique adult plants, or approximately 1,243 individuals (determined as the minimum number of individuals observed in a single year over spans of 10 to 15 years) to maintain a 90% probability of species persistence over the next 100 years.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Occupies ~36.6 ha (90.4 ac) of habitat dispersed within an ~631.7 ha (1,561.0 ac) occurrence area.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Unknown; analysis of existing data needed.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Distances between next nearest populations range from a minimum of 4.0 km (2.5 mi) to a maximum of 45.3 km (28.1 mi). The distance across the species range is 59.8 km (37.2 mi). The count of subpopulations within populations ranges from 3 to 80. Distance between populations creates a substantial barrier to gene flow; populations are isolated and unlikely to interbreed.
Suitable Habitat	Geological Substrates	Evaporites that contain gypsum deposits or hypergypsic (>40% gypsum) facies within evaporites.
Suitable Habitat	Soils	Hypergypsic, slightly alkaline, loose, moderately developed (≥ 13 cm (5 in) in depth) clay soils.
Suitable Habitat	Moisture	Semi-arid environments with most precipitation occurring between May and September. Possibly capable of accessing water from hydrated gypsum (crystallization water) during drought. Winter precipitation is required to overcome dormancy in year 1, and growing season precipitation is required for seedling establishment and survival.
Suitable Habitat	Solar Exposure	Low, sparse canopy cover; gentle to moderate slopes (0 to 33°, 0 to 65%).
Suitable Habitat	Associated Species Matrix	*Tiquilia hispidissima/Sporobolus nealleyi - Tidestromia carnosa* Gypsum Outcrop & Alluvial Flat Desert Scrub Alliance; *Anulocaulis gypsogenus, Bouteloua breviseta, Tiquilia hispidissima, Aristida purpurea, Nama carnosa, Castilleja sessiliflora, Zeltnera maryanna, Euphorbia chaetocalyx, Ephedra torreyana, Mentzelia humilis, Thelesperma megapotamicum, Krameria erecta, Nerisyrenia linearifolia, Oenothera gayleana, Polygala alba, Poliomintha incana*.
Suitable Habitat	Disturbance Regime	Intermittent, low-intensity and small-extent, dispersed disturbance
Suitable Habitat	Other	Symbiotic relationships with arbuscular mycorrhizal fungus and/or other rhizosphere microorganisms are likely.

Need	Factor	Species Characteristics
Suitable Climate	Precipitation	336 mm (13.24 in) to 347 mm (13.67 in) annually
Suitable Climate	Temperature	Average low of -3.0°C (26.6°F) in January to an average high of 34.6°C (94.2°F) in July.

A.2.11 Todsen's Pennyroyal (Hedeoma todsenii)

Family: Lamiaceae

Federal status: Endangered, with designated critical habitat

A.2.11.1 General Summary

Todsen's pennyroyal (*Hedeoma todsenii* R.S. Irving) is an herbaceous perennial with slender rhizomes giving rise to unbranched, clustered stems that are slightly woody at the base and up to 20 cm (8 in) tall. It has 1–2 red-orange to red-yellow flowers per stem. The plant is known from only two mountain ranges in New Mexico: the San Andres Mountains in Sierra County, and the Sacramento Mountains in Otero County. It grows on steep slopes with gypseous limestone soils in piñon-juniper woodlands.

A.2.11.2 Threats

- Small population size.
- Wildfire.
- Grazing.
- Wildlife browsing.
- Insect herbivory.
- Low reproduction rates.
    - Probable inbreeding depression and genetic drift.
- Mineral exploration.

A.2.11.3 Recovery and Conservation Needs

- Research reproductive biology, growth requirements, genetics, and fire effects.
- Remove trespassing livestock.
- Monitor and alleviate erosion.
- Establish a working group for agency and public coordination.

Table A.11. Species needs for Todsen's pennyroyal (*Hedeoma todsenii*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Appears to be mostly asexual rhizomatous reproduction; sexual reproductive output (seed set) is low and varies temporally (potentially due to inbreeding depression causing reduced fecundity). Self-pollination, pollination between flowers in a patch, and pollination between patches of a population all resulted in some seed production. Therefore, self-incompatibility or inbreeding alone are probably not the causes of low seed production. Sexual reproduction is likely dependent on pollen vectors, moisture availability, and other environmental factors. There may be positive relationships between canopy cover and seed set and moisture and seed set. Propagules for revegetation may be cultivated through stem tissue and cryogenically stored as an alternative to seed banking.
Reproduction	Reproductive Season (Budding to Seeding)	Flowers bimodally (early monsoons and late monsoons), dependent on rainfall, typically late April to July and August to November. Peak bloom time is typically June 15–July 15 and September 15–October 15. Fruits develop 4–6 weeks after anthesis.
Reproduction	Pollinators	Primarily wasps (Sphecidae); rarely, broad-tailed hummingbird.
Dispersal	Mechanism/ Agents	Gravity: calyces retain the nutlets and are dispersed as a unit.
Dispersal	Distance	Calyces and nutlets have been observed to remain in the immediate vicinity of the parent plant, and nutlets become mucilaginous and stick to ground cover/soil when wet, preventing movement with surface run-off.
Germination	Germination Requirements	Seeds become mucilaginous when moistened, increasing adherence to the soil. When sampled, 25% of seeds were viable, and (assuming this viability rate) 20% of viable seeds germinated; therefore, seeds may have strict germination requirements.
Seed Bank	Soil Seed Bank Duration	Unknown; research needed.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Likely a relict species. Occurs in south-central New Mexico in the San Andres Mountains of Sierra County and the Sacramento Mountains in Otero County. 1,890–2,256 m (6,200–7,400 ft).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	121 km (75 mi) between two population areas.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	There are 15 Sacramento Mountains sites and, in the San Andres Mountains, eight sites near Domingo Peak and seven sites near Mountain Lion Peak; sites often consist of thousands of stems of unknown individuality. The sites may not be separate populations in a biological sense.
Suitable Habitat	Geological Substrates	Permian Yeso formation.
Suitable Habitat	Soils	Gypseous sandy loam, often with loose limestone gravel and cobble (calcareous soils with high sand and silt content and good nutrient availability and water-holding capacity), commonly with a thin layer of conifer litter. This species has grown well in potting soil with calcium sulfate added, suggesting it's affinity to certain soils may be based on soil structure and water holding capacity and not chemical composition.
Suitable Habitat	Moisture	High water penetration and holding capacity; found in microsites where soils are moister than the surrounding areas.
Suitable Habitat	Solar Exposure	Steep (20–70°), north-facing slopes or level terraces along intermittent streams; limited direct sun exposure and evaporation potential.
Suitable Habitat	Associated Species Matrix	Mesic sites within piñon-juniper communities and scattered ponderosa pine and Douglas-fir woodlands: *Cercocarpus montanus, Garrya flavescens, Hymenopappus radiatus, Gutierrezia* sp., *Juniperus* sp., *Muhlenbergia* sp., *Pinus edulis,* and *Quercus x pauciloba.*
Suitable Habitat	Disturbance Regime	Only occurs in rugged and remote areas with no vehicle traffic and minimal land use.

Need	Factor	Species Characteristics
Suitable Habitat	Other	N/A
Suitable Climate	Precipitation	Avg. ≥356 mm (14 in) annually. PRISM: 257–531 mm (10.1–20.9 in).
Suitable Climate	Temperature	Avg. 190 frost-free days. PRISM: avg. low = -0.9°C (30.4°F), avg. high = 27.8°C (82.1°F).

A.2.12 Pecos Sunflower (Helianthus paradoxus)

Family: Asteraceae

Federal status: Threatened, with designated critical habitat

A.2.12.1 General Summary

The Pecos sunflower (*Helianthus paradoxus* Heiser) is a 1–3 m (3–10 ft) tall, annual forb that branches at the top. Leaves are opposite on the lower stem and alternate towards the top. Disc flowers are purplish-brown and ray flowers are yellow (although some plants at the Bitter Lake population display a morph possessing bright red ray flowers, tipped with yellow). Compared to common sunflower (*Helianthua annuus*), Pecos sunflower has narrower leaves, fewer hairs, and smaller flower heads. This wetland obligate species grows in alkaline, perennially wet soils around desert springs (ciénegas) and ponds in Valencia, Socorro, Guadalupe, Cibola, and Chaves counties, New Mexico and Pecos and Reeves counties, Texas.

A.2.12.2 Threats

- Loss and alteration of wetlands (diversion of water for irrigation, agriculture, livestock, etc. and lowered water tables).
- Climate change (warmer temperatures and increased drought).
- Invasive species (e.g., saltcedar, Russian olive).
- Native species encroachment (e.g., common reed).
- Mowing.
- Livestock (foraging and trampling, especially foraging on developing buds).
- Possibly water contamination from oil and gas.

A.2.12.3 Recovery and Conservation Needs

- Identify and establish conservation areas.
- Protect core conservation areas and isolated stands through landowner education, management plans, conservation easements, or land acquisition.
- Identify and address knowledge gaps, compatible land uses, and management actions.
- Monitor conservation and management areas.

Table A.12. Species needs for Pecos sunflower (*Helianthus paradoxus*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Outcrossing; limited selfing with greatly reduced seed set.
Reproduction	Reproductive Season (Budding to Seeding)	Flowers August–October; seeds fill and mature October–November (Texas population is on the later end of this range).
Reproduction	Pollinators	Unknown but asters are usually pollinated by a variety of insects.
Dispersal	Mechanism/ Agents	Unknown; research needed.
Dispersal	Distance	Unknown; research needed. Seedlings have casually been observed at high density within ~20 m (66 ft) of occupied patches and, at lower densities, as far away as ~50 m (164 ft).
Germination	Germination Requirements	Germination occurs in the year following seed set in early March through April (after killing frost), about 4–6 months after dispersal. Seeds undergo a 2–3month after-ripening period before germination can occur. Seeds germinate best when high precipitation and water tables reduce salinity near the soil surface; however, some evidence suggests that rainfall amounts in winter and early spring are more important for germination than groundwater levels. High seedling density has been found in thick saltgrass cover.
Seed Bank	Soil Seed Bank Duration	Seed viable possibly up to 5 years. While most seeds germinate in the year following seed set, a few seeds remain dormant for longer periods and appear to remain viable in the soil seed bank.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Research needed; At least 5,000 individuals in core habitat, 1,600 in isolated stands.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Seven widely spaced populations in eastern New Mexico and Trans-Pecos Texas, 1,006–2,012 m (3,300–6,600 ft).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Most patches are less than 2 ha (5 ac) in area and may be up to 13 km (9 mi) apart within a metapopulation area.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Discontinuous distribution, 64–161km (40–100 mi) between populations. Within populations, solitary individuals may be found around the periphery of the wetland, but dense, well-defined stands within suitable habitats are more typical. The patches of sunflowers are not static within a ciénega. Aggregations of live individuals may occur in different adjacent areas than the patches of dead stalks from the population of the previous year. Patch densities and locations are determined by a combination of factors including seasonal soil moisture variations, soil salinity, soil oxygen, soil disturbance, and competing vegetation.
Suitable Habitat	Geological Substrates	No specific geology parent material or substrate identified.
Suitable Habitat	Soils	Saturated (but only intermittently inundated), alkaline, silty clays or fine sands with high organic content and salinity levels ranging from 10–40 parts per thousand.
Suitable Habitat	Soil Moisture	Saturated below the surface in the rhizosphere, moist to dry at the surface.
Suitable Habitat	Solar Exposure	Low proportion of woody shrub or canopy cover in the immediate area.
Suitable Habitat	Associated Species Matrix	Desert wetlands (ciénegas), springs, and stream and lake margins; *Agalinis calycina, Apocynum cannabinum, Baccharis salicina, Distichlis* sp., *Elaeagnus angustifolia* (invasive), *Flaveria chlorifolia, Juncus balticus* ssp. *littoralis, Juncus mexicanus, Limonium limbatum, Muhlenbergia asperifolia, Phragmites australis, Samolus ebracteatus* ssp. *cuneatus, Schoenoplectus americanus, Scirpus olneyi, Solidago canadensis, Sorghastrum nutans, Sporobolus airoides, Suaeda calceoliformis, Tamarix* spp. (invasive), *Cirsium wrightii,* and *Spiranthes magnicamporum*.
Suitable Habitat	Disturbance Regime	Responds positively to fire (and associated nutrient pulses) and tilling but negatively to grazing. Found in disturbed areas where competition with perennial plants is limited. Grazing during non-flowering periods may be beneficial by decreasing competition.

Need	Factor	Species Characteristics
Suitable Habitat	Other	Adapted to saline soils (replaces potassium with sodium and magnesium in its tissue to supplement osmotic pressure and increases leaf succulence to mitigate the toxic effects of sodium). Plants grow larger and have higher fecundity in areas with lower competition/plant density.
Suitable Climate	Precipitation	PRISM: 259–320 mm (10.2–12.6 in).
Suitable Climate	Temperature	PRISM: avg. low = -4.1°C (24.7°F), avg. high = 30.1°C (86.1°F).

A.2.13 Holy Ghost Ipomopsis (Ipomopsis sancti-spiritus)

Family: Polemoniaceae

Federal status: Endangered, without designated critical habitat

A.2.13.1 General Summary

Holy Ghost ipomopsis (*Ipomopsis sancti-spiritus* Wilken & Fletcher) is an herbaceous biennial to short-lived perennial with a basal rosette of pinnatifid leaves with 9–15 linear divisions. The upper half of flowering stems are topped with an inflorescence of 6–11 clusters of pink, tubular flowers with five spreading to slightly reflexed lobes. Individuals are monocarpic, meaning they flower once and then die. The plant is known from a single location in Holy Ghost Canyon, a tributary of the Pecos River in the Sangre de Cristo Mountains in San Miguel County, New Mexico. The natural setting it occurs in is characterized as having an open canopy with minimal tree cover (usually conifers), minimal brush/shrub species, and steep slopes with sloughing, mobile soils.

A.2.13.2 Threats

- Small population sizes (risk of genetic drift and inbreeding depression).
- Road maintenance.
- Recreation.
- Wildlife browsing.
- Wildfires and firefighting activities.
- Climate change (warmer temperatures and increased drought).
- Non-native species (e.g., smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*)).
- The use of *Bacillus thuringiensis* (BT) as an insecticide to kill budworm on Douglas-fir may harm important Holy Ghost ipomopsis pollinators.

A.2.13.3 Recovery and Conservation Needs

- Reintroduce plants to the Pecos River Basin and protect existing populations.
  - Collect seeds, germinate, outplant, increase seed yields.
- Monitor and manage plant populations and human activities.
- Avoid resource extraction.
- Conduct population viability analyses at existing and introduced sites to evaluate success and understand reproduction; research habitat and biological requirements, community dynamics, and pollinators.

- Create a fire management plan and integrate the plant into post-fire restoration plans.
- Find new occurrences.
- Encourage public awareness.

Table A.13. Species needs for Holy Ghost ipomopsis (*Ipomopsis sancti-spiritus*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Outcrossing; limited selfing with reduced fruit set (selfing may also require a pollinator to move pollen from anther to stigma). Has been successfully propagated from seed in greenhouses, but propagated plants had low fecundity, possibly due to low pollinator abundance.
Reproduction	Reproductive Season (Budding to Seeding)	Flowers late July through mid-September.
Reproduction	Pollinators	Moths and butterflies; observers have documented eight species of arthropods visiting plants, with three species appearing to be the most common: Snow's skipper (*Paratrytone snowi*), golden skipper (*Poanes taxiles*), and sphinx moth (*Hyles lineata*).
Dispersal	Mechanism/ Agents	Unknown; research needed.
Dispersal	Distance	Unknown; research needed.
Germination	Germination Requirements	Seeds require cold stratification and may also require after-ripening and warm stratification. In propagation, seeds are held in dry storage for two months, cold-treated for six weeks at 4°C (40°F), and then sown in moist soil at 21–27°C (70–80°F); emergence occurs 5–25 days after sowing. Germination rates in trials were ~70–90%, with trials showing that 4–8 weeks of cold treatment increases germination. Seeds likely germinate in the spring or early summer.
Seed Bank	Soil Seed Bank Duration	Unknown; research needed. No plants germinated from Holy Ghost Canyon surface soil samples exposed to favorable gemination conditions.

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	100 flowering plants based on *I. aggregata* studies; ~25% of Holy Ghost ipomopsis flower each year, indicating that ~400 plants are required for a viable population.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Endemic to one location; there are about 80 ha (200 ac) of occupied habitat. 2,356–2,505 m (7,730–8,220 ft).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Unknown; analysis of existing data needed. Population is 3.5 km (2.2 mi) in length.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Narrow endemic; one known natural population. Plants are relatively continuous in scattered patches for about 3.5 km (2.2 mi) of Holy Ghost Canyon. Plant distribution ranges from isolated plants greater than 50 m (164 ft) from the next nearest plant to small, dense (5 plants/m^2 (0.5/ft^2)) patches. About 80% of the population grows on, or immediately adjacent to, west-facing cutslopes along a Forest Road.
Suitable Habitat	Geological Substrates	Partly weathered Terrero Limestone.
Suitable Habitat	Soils	Soils derived from Terrero Limestone, grows best on bare mineral soils.
Suitable Habitat	Moisture	Unknown moisture requirements. Grows on dry, steep canyon slopes, excluding riparian areas.
Suitable Habitat	Solar Exposure	South, west, and southwest aspects; open, full sun.
Suitable Habitat	Associated Species Matrix	Openings in ponderosa pine and Douglas fir forests with low densities of other perennial plants; *Achillea millefolium, Allium cernuum, Apocynum cannabinum, Brickellia grandiflora, Cercocarpus montanus, Erigeron speciosus, Hymenopappus newberryi, Pinus ponderosa, Populus tremuloides, Pseudotsuga menziesii, Quercus gambelii, Rosa woodsii,* and *Toxicodendron rydbergii.*

Need	Factor	Species Characteristics
Suitable Habitat	Disturbance Regime	Grows at higher densities in disturbed sites and likely requires stochastic natural disturbances to open habitat niches; however, anthropogenic soil disturbance can facilitate introduction and spread of weedy, non-native plants that could out-compete Holy Ghost ipomopsis for early-successional niches.
Suitable Habitat	Other	N/A
Suitable Climate	Precipitation	Avg. 406 mm (16.2 in) annually. PRISM: avg. 490–536 mm (19.3-21.1 in).
Suitable Climate	Temperature	PRISM: avg. low = -4.7°C (23.6°F), avg. high = 18.2°C (64.8°F).

A.2.14 Knowlton's Cactus (Pediocactus knowltonii)

Family: Cactaceae

Federal status: Endangered, without designated critical habitat

A.2.14.1 General Summary

Knowlton's cactus (*Pediocactus knowltonii* L. Benson) is a very small, typically single-stemmed cactus with a multi-stemmed condition occurring in response to damage, burial, or other disturbances. Reproductive plants produce 1–2 pink flowers per stem that bud in early autumn and overwinter before blooming in May. Spring flowering is therefore greatly influenced by the previous growing season and winter conditions. The cactus is known from a single natural population where plants occupy a small hill in San Juan County, New Mexico. This hill is located on Tertiary alluvial deposits that form rolling, gravelly hills occupied by piñon-juniper woodlands and sagebrush on the San Jose formation.

A.2.14.2 Threats

- Climate change (warmer temperatures and increased drought).
- Oil and gas development (habitat fragmentation).
- Seed and plant predation by rodents, rabbits, and caterpillars.
- Small population size (potential for inbreeding depression).
- Illegal collection.

A.2.14.3 Recovery and Conservation Needs

- Remove existing threats.
    - Enforce existing regulations, analyze threats, manage for optimal protection.
- Maintain viable populations in their natural habitat.
- Develop a comprehensive cactus trade plan.
- Develop public awareness, appreciation, and support.

Table A.14. Species needs for Knowlton's cactus (*Pediocactus knowltonii*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Research needed; other rare *Pediocactus* spp. are cross-pollinating and self-incompatible.
Reproduction	Reproductive Season (Budding to Seeding)	Plants become reproductive at 1 cm (0.4 in) diameter or more. Buds form in early autumn and overwinter before blooming in May-June, and fruits ripen in late June. Fruits dehisce from mid- to late-June.
Reproduction	Pollinators	Research needed; other, rare *Pediocactus* spp. are pollinated by small native bees. Cacti do not flower simultaneously, so planting in clusters may increase pollinator visitation.
Dispersal	Mechanism/ Agents	In some years, rodent predation on unripe fruits prevents seed dispersal (rodents are unlikely to be dispersers, given lack of evidence of population expansion); without predation, fruits dehisce from mid- to late-June, and seeds fall close to the parent plant.
Dispersal	Distance	Unknown; research needed.
Germination	Germination Requirements	Very little information on cactus propagation from seed, see Mesa Verde Cactus (*Sclerocactus mesae-verdae*) for possible similarities. One study showed direct seeding to be more effective than transplanting clones. In experiments, only 4% of the planted seeds established, suggesting germination requirements. Evidence also suggests that microhabitat suitability restricts germination and recruitment.
Seed Bank	Soil Seed Bank Duration	Unknown, but it's thought that planted seeds declined in viability after eight years in the soil.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed. Recovery criterion is at least 7,500 individuals maintained over a 20-year survey period.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Only a single, natural population consisting of 3,500 plants (as of 2021) within 4 ha (10 ac), 1,890–1,920 m (6,200–6,300 ft). There is also another small, introduced population on BLM lands consisting of ~160 plants (as of 2021).

Need	Factor	Species Characteristics
Adequate Abundance, Distribution, and Connectivity	Patch Distance	N/A
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Narrow endemic; known from a single natural population.
Suitable Habitat	Geological Substrates	Tertiary alluvial deposits overlying the San Jose formation (Eocene).
Suitable Habitat	Soils	Gravelly alluvium.
Suitable Habitat	Moisture	Specific moisture requirements unknown.
Suitable Habitat	Solar Exposure	Full sun or partial shade.
Suitable Habitat	Associated Species Matrix	Piñon-juniper/sagebrush: *Artemisia nova, Juniperus scopulorum, Parmelia* sp. (foliose lichen that occurs in high abundance), and *Pinus edulis*.
Suitable Habitat	Disturbance Regime	The cactus' ability to sprout new stems in response to damage or burial suggests resiliency to minor disturbances.
Suitable Habitat	Other	N/A
Suitable Climate	Precipitation	Avg. 310 mm (12.2 in) annually, mostly in late summer and winter months. PRISM: ~180 mm (7.1 in). Has contractile roots, enabling the plant to sink below the soil surface during periods of drought.
Suitable Climate	Temperature	PRISM: avg. low = -4.2°C (24.4°F), avg. high = 25.9°C (78.6°F).

A.2.15 Mesa Verde Cactus (Sclerocactus mesae-verdae)

Family: Cactaceae

Federal status: Threatened, without designated critical habitat

A.2.15.1 General Summary

Mesa Verde cactus (*Sclerocactus mesae-verdae* (Boissevain ex Hill & Salisbury) L. Benson) is a small, typically single-stemmed, cactus with inconspicuous tubercles, woolly aereoles, and straw-colored, spreading radial spines. Stems commonly branch above and below-ground, making it difficult to identify individuals. It has yellowish-cream to pinkish flowers. Its fruits are green and become tan at maturity. While plants live around 20 years on average, individuals may live up to 50 years and reach up to 19 cm (7.5 in) in diameter. Mesa Verde cactus is known from the Four Corners region in New Mexico (San Juan County) and Colorado (Montezuma County), within which occurrences are sporadic and widely scattered. The majority of the occupied habitat consists of Mancos Shale, which is a silty sediment of marine origin that is highly alkaline and saline. A relatively small portion of the total habitat occurs on the east side of the Farmington Hogback near Waterflow, New Mexico, on Fruitland Shale, which is fluvial in origin. This shale is highly sodic and contains quantities of selenite gypsum.

A.2.15.2 Threats

- Oil and gas development (considered most severe threat with ORV use).
- Off-road vehicles (directly and indirectly, via erosion, invasive plants, change in soil biota and physical structure, fugitive dust).
- Climate change (drought and warmer temperatures).
- Predation by rodents, rabbits, and insects (especially from larvae of a frequent pollinator of the cactus, the native longhorn beetle (*Moneilema semipunctatum*), and the non-native army cutworm (*Euxoa* spp.)).
- Urban development.
- Grazing and trampling.
- Powerlines and powerline maintenance.
- Road construction and maintenance.
- Illegal collection.
- High seedling mortality (desiccation).
- Burial by ground squirrels.
- Possibly the invasive annual plant *Halogeton glomeratus*, which increases soil salinity.

A.2.15.3 Recovery and Conservation Needs

- Protect existing populations.
- Create restricted use areas for habitat.
- Propagate plants for collector demand to reduce illegal wild collection.
- Research the biology, ecology, pollinators, and distribution of the species to inform management.
  - Closely monitor population trends, search for new populations.
- Research causes of population decline.
- Create seed banks and propagate plants for population augmentation/reintroduction.

Table A.15. Species needs for Mesa Verde cactus (*Sclerocactus mesae-verdae*).

Need	Factor	Species Characteristics
Reproduction	Breeding System	Outcrossing and selfing (between two flowers on the same plant but not within one flower), with selfing yielding ~50% fewer seeds than outcrossing; vegetative asexual reproduction (potentially triggered by disturbance) from live and dislocated stems. Pollen grains average ~90% viability.
Reproduction	Reproductive Season (Budding to Seeding)	Reproductive maturity at 2–8 years (~2 cm (0.8 in) diameter); stems sprouting from existing plants may flower the same year. Flowers bloom late April through early May; each flower is diurnal (opens during the day) and lasts 2–5 days. Fruits mature in late May and average 200 seeds per plant (~20–30 seeds/fruit); they dehisce in mid- to late-June. The number of reproductive structures is positively correlated with individual stem diameter.
Reproduction	Pollinators	Solitary bees, including the metallic green sweat bee in the Halictidae family; fungus beetles (*Tritoma* sp.), blister beetles (*Epicauta* sp.), and other Coleoptera (beetles); and Hymenoptera (wasps, ants, bees, sawflies) have been observed on plants, but their effectiveness as pollinators is unknown.
Dispersal	Mechanism/ Agents	Harvester ants (*Pogonomyrmex* sp.), rain, wind, and possibly frugivores (rodents, birds, lizards, mammals), which feed on fruits with unknown dispersal effectiveness.

Need	Factor	Species Characteristics
Dispersal	Distance	One study found on average 200 seeds within a one-meter radius of mature plants and 80% of seeds at 0–3 cm (0–1.2 in) soil depth.
Germination	Germination Requirements	Cool, moist spring season conditions increase germination. Thought to germinate after, or with, summer monsoons and increased temperatures and establish through early fall, forming clumps which may be clones or separate individuals (seeds often fall into crevices suggesting clumps are composed of genetically unique individuals that germinate separately from congregated seeds). Soil cracks are thought to provide important microhabitats for establishment. Freezing and thawing (vernalization), seed coat scarification, and proper temperature, light, and moisture are necessary for germination. Does well in cultivation, suggesting ex-situ propagation may be a suitable conservation strategy, though early attempts report high rates of damping off among seedlings.
Seed Bank	Soil Seed Bank Duration	Research needed; one observation suggests seedbank persistence for up to six years in Sonoran cacti.
Adequate Abundance, Distribution, and Connectivity	Viable Population Size	Unknown; research needed.
Adequate Abundance, Distribution, and Connectivity	Occurrence Area	Occurs sporadically and widely scattered within an area 121 x 48 km (75 x 30 mi) in extent, between Cortez, Colorado, and Sheep Springs, New Mexico. 1,402–1,999 m (4,600–6,560 ft).
Adequate Abundance, Distribution, and Connectivity	Patch Distance	Unknown; analysis of existing data needed.
Adequate Abundance, Distribution, and Connectivity	Distribution Pattern	Geographically restricted; 5 major population areas with clumpy distribution within each.
Suitable Habitat	Geological Substrates	Cretaceous Mancos shale in Colorado; Fruitland and Mancos shales in New Mexico.

Need	Factor	Species Characteristics
Suitable Habitat	Soils	Highly alkaline (pH 7.5–8), saline, and sodic and/or gypsiferous clay loam soils with shrink-swell tendencies, prone to surface cracking. Elevated levels of sodium, calcium, selenium, and iron. Low levels of organic matter, phosphate, and nitrate. Seen growing in gravel, but commonly grows in bare soil.
Suitable Habitat	Moisture	Specific moisture requirements unknown; suffered a significant population decline after the 2002/2003 drought.
Suitable Habitat	Solar Exposure	Full sun.
Suitable Habitat	Associated Species Matrix	Sparsely vegetated Great Basin Desert Scrub (Saltbush Series) and Desert Grassland Ecotone communities on low rolling hills, particularly hilltops and benches: *Atriplex corrugata* (found to be a dominant shrub in both Colorado and New Mexico populations and may be a nurse shrub for the cactus), *Atriplex* spp., *Bromus tectorum* (invasive), *Eriocoma hymenoides*, *Frankenia jamesii*, *Picrothamnus desertorum, Phlox longifolia*, *Pleuraphis jamesii*, *Salsola tragus* (invasive), and *Sporobolus cryptandrus*.
Suitable Habitat	Disturbance Regime	No specific disturbance regime noted in literature.
Suitable Habitat	Other	N/A
Suitable Climate	Precipitation	178 mm (7 in) in Shiprock, New Mexico, ranging, on avg, from ~76–203 mm (3–8 in), annually. PRISM: 170–348 mm (6.7–13.7 in).
Suitable Climate	Temperature	PRISM: avg. low = -3.9°C (24.9°F), avg. high = 28.6°C (83.5°F). Individuals may shrink and retract back into soil during unfavorable temperatures, minimizing desiccation or dehydration.

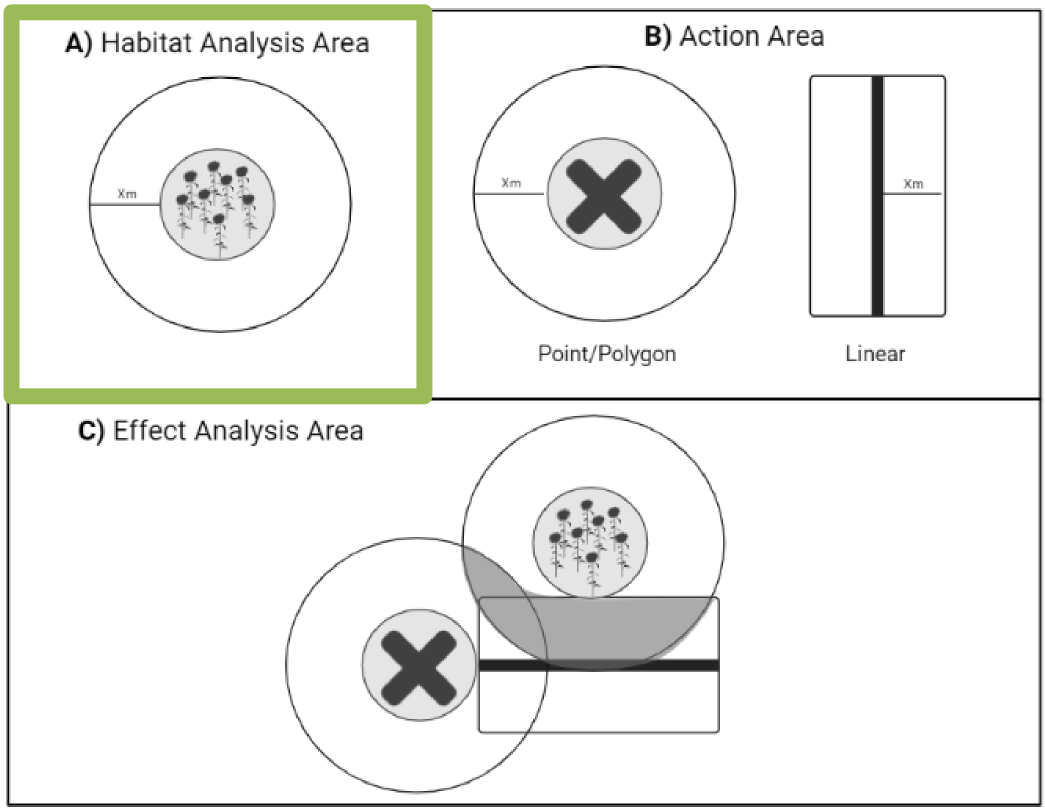
A.3 References

Maschinski, J., M. A. Albrecht, L. Monks, and K. E. Haskins. 2012. Center for plant conservation best reintroduction practice guidelines. In *Plant reintroduction in a changing climate: Promises and perils*, ed. J. Maschinski and K. E. Haskins, 277–306. Washington: Island Press.

PRISM Climate Group. n.d. Recent Years (Jan 1981 - Nov 2022). *Northwest Alliance for Computational Science and Engineering*.

Rabinowitz, D. 1981. Seven forms of rarity. In *The biological aspects of rare plant conservation*, ed. H. Synge, 205–217. Chichester, West Sussex, England: John Wiley & Sons.

Appendix B Methodology for Delineating Habitat Analysis Areas for Threatened and Endangered Plant Species in New Mexico



Prepared By:

Institute for Applied Ecology

For:

U.S. Fish & Wildlife Service

New Mexico Ecological Services Field Office

May 2024

Page intentionally left blank.

Table of Contents

List of Figures

List of Tables

B.1 Introduction

A Habitat Analysis Area (HAA) represents the physical area (including and surrounding the direct footprint of a species' occurrence) within which activities could potentially (adversely or beneficially) affect a population's viability. Neither HAAs nor their recommended delineation distances represent "avoidance buffers." Rather, they represent areas/distances within which we recommend assessing potential effects to species' ecological and biological needs. HAA delineation distances differ between HAA groups because species traits make them more or less sensitive or resilient (and, therefore, vulnerable) to environmental perturbations. More sensitive and/or less resilient species may be affected from greater distances. Our recommended HAA delineation distances in **Recommendations for Endangered Species Act Section 7 Consultations Involving Plants in New Mexico** were determined via the systematic scoring process outlined in this document (also known as the "HAA Rubric"). This rubric assesses a species' spatial vulnerability based on the sensitivity of its reproductive, demographic, and habitat traits.

B.2 Delineating HAAs for Species with a Single Known Natural Occurrence

Species with a single known naturally occurring population (single-site endemics) lack redundancy because they have no alternative populations to serve as a propagule source or to compensate for localized extirpations. Lack of redundancy reduces a species' adaptive capacity and, hence, resiliency. Therefore, single-site endemics are highly vulnerable to extinction. Because their vulnerability is high independent of their sensitivity, their HAA distance is <u>1,000 meters (m)</u> (3,281 feet (ft)) to ensure that exposure to all potential effects is analyzed. Table 5.1 in **Recommendations for Endangered Species Act Section 7 Consultations Involving Plants in New Mexico** includes a list of all the currently listed species with a single known natural occurrence. For some single-site endemics (e.g., Holy Ghost ipomopsis), recovery actions have been implemented to propagate and introduce populations outside of the current, naturally occurring population area. These introduced populations of single site endemics should be given the same HAA value as naturally occurring populations due to experimental nature of introduction efforts and uncertainty of long-term viability of introduced populations.

B.3 Delineating HAAs for Wetland Obligate Species

Plant species that rely on wetland habitats warrant special considerations for delineating HAAs. Table 5.1 in **Recommendations for Endangered Species Act Section 7 Consultations Involving Plants in New Mexico** includes a list of all the currently listed wetland obligate species. Many wetlands in New Mexico are groundwater dependent ecosystems (GDEs), ecological communities of species that depend on groundwater for survival. Plant species that occur in wetland ecosystems typically require permanently or seasonally saturated soils, or at least elevated soil moisture levels. Because of their association with surface or subsurface water, wetland plant species are more likely to be impacted by activities that alter hydrology. Hydrology can be altered on multiple scales, with potential for highly compounding adverse impacts to wetland plants.

Figure B.1. Watershed Boundary Dataset structure (National Hydrography 2018).

The minimum HAA for wetland species should be delineated (at an appropriate scale to capture upstream and downstream influences on a listed plant or its designated critical habitat) according to Watershed Boundary Dataset hydrologic units. Two-digit hydrologic units represent regions, four-digit hydrologic units represent subregions, six-digit hydrologic units represent basins, eight-digit hydrologic units represent subbasins, ten-digit hydrologic units represent watersheds, and twelve-digit hydrologic units represent subwatersheds (see Figure B.1). Hydrologic unit boundaries "are determined based on topographic, hydrologic, and other relevant landscape characteristics without regard for administrative, political, or jurisdictional boundaries" (National Hydrography n.d.).

B.4 Rubric for Assigning Provisional HAA Groupings

The following section is a rubric detailing which and how biological, demographic, and ecological traits were assessed to assign species into HAA groups. **The rubric was not applied to species with a single known natural occurrence or wetland species.** Methods for those species are described in sections B.2 and B.3 above.

Six traits (three reproductive traits and three demographic/habitat traits) were scored according to the system outlined in tables B.4.1-B.4.6 below. Scores represent the relative sensitivity of trait attributes to environmental perturbations, with lower scores representing lower sensitivity and higher scores representing higher sensitivity. Two traits (population abundance and habitat specificity/rarity) are multiplied by two to weight their importance to overall species' vulnerability. The total score for each species is summed and taken as a percent of the total possible score (24). These percentages were then used to place species into groups according to the following ranges:

- 58-69% = HAA Group 1
- 70-79% = HAA Group 2
- ≥ 80% = HAA Group 3

Results and rationales for each species' HAA designation are summarized in **B.5 Rubric Results for Provisional HAA Groupings**. Table 5.1 in **Recommendations for Endangered Species Act Section 7 Consultations Involving Plants in New Mexico** contains lists of species by HAA group and each group's associated HAA delineation distance value.

B.4.1 Reproductive Traits

B.4.1.1 Mating System

The mating system is the mechanism by which species reproduce: sexually (via outcrossing or selfing) or asexually (via vegetative clonality). Plants can display a spectrum of mating systems, ranging between entirely selfing (self-compatible) to entirely outcrossing (self-incompatible), and can include mixed mating systems with varying degrees of selfing and outcrossing capabilities within and across individuals and populations. Due to their dependence on pollinators to carry pollen to conspecifics, self-incompatible (i.e., outcrossing) species are more susceptible to the effects of habitat fragmentation than their self-compatible (i.e., selfing, inbreeding) counterparts. Therefore, species with higher dependence on outcrossing receive higher scores.

Table B.4.1. Scoring guidelines for assessing a species' mating system.

Score	Mating System
0	Primarily or entirely selfing or clonal.
1	A mix of selfing, clonal, and/or outcrossing breeding systems without reduced offspring viability or fitness resulting from selfing or cloning.
2	A mix of selfing, clonal, and/or outcrossing breeding systems with reduced offspring viability or fitness resulting from selfing or cloning and/or species with some mechanism to minimize selfing (i.e., protandry).
3	Primarily or entirely outcrossing.

B.4.1.2 Pollination

In sexually reproducing species, pollination is the mechanism by which pollen is transported from anther to stigma. Species that have pollination syndromes that are more likely to be adversely affected by loss of pollinator habitat or life cycle interference are assigned a higher score. Primarily selfing or clonal species and species with higher pollen dispersal distances have lower scores because pollen movement is less vulnerable to habitat fragmentation.

Table B.4.2. Scoring guidelines for assessing a species' pollination mechanism.

Score	Pollination
0	Primarily or entirely selfing or clonal.
1	Pollinated by wind, birds, bumblebees, or larger insects with intermediate to long average foraging distances (> 500 m (> 1,640 ft)).
2	Pollinated by small insects with limited average foraging distances (≤ 500 m (≤1,640 ft)).
3	Pollinated exclusively or primarily by a pollinator specialist.

B.4.1.3 Seed Dispersal Mechanism

The seed dispersal mechanism is the force or agent by which seed is dispersed away from the parent plant. Species with dispersal mechanisms that carry seed further distances are assigned lower scores because risk of seed bank loss from a stochastic event and/or restriction of dispersal by habitat fragmentation is lower.

Table B.4.3. Scoring guidelines for assessing a species' seed dispersal mechanism.

Score	Seed Dispersal Mechanism
0	Long-distance dispersal; i.e., primarily dispersed by birds or large animals.
1	Moderate-distance seed dispersal; i.e., aerodynamic or buoyant seeds that are primarily dispersed by wind or water.
2	Local dispersal; i.e., primarily dispersed by small mammals or non-aerodynamic and non-buoyant seeds that are dispersed by wind or water.
3	Immediate vicinity dispersal; i.e., primarily dispersed by gravity or small, non-winged insects, such as ants.

B.4.2 Demographic and Habitat Traits

B.4.2.1 Distribution Pattern

The distribution pattern describes how individuals are distributed in space relative to one another (e.g., the arrangement of individuals within populations and the arrangement of populations within a species' range). The distribution pattern affects a species' connectivity (the degree to which population areas are able to interbreed with, or disperse within, one another). Species that occur in isolated patches are given a higher score because they are less resilient to, and less capable of rescuing[1] other population areas from, stochastic events and chronic effects that occur within some distance from the population.

Table B.4.4. Scoring guidelines for assessing a species' distribution pattern.

Score	Species Distribution Pattern
0	Well-connected distribution (common genetic exchange); i.e., exists as an abundant and widespread mega-population.
1	Inter-connected distribution (subpopulations capable of periodic interbreeding); i.e., exists as a single, widespread meta-population or as a rare and widespread mega-population, where patches or individuals are typically within 500 m (1,640 ft) of one another.
2	Sparsely inter-connected distribution (potential to interbreed but have barriers to gene flow); i.e., exists as a single, widespread meta-population or as a rare and widespread mega-population, where patches or individuals are typically greater than 500 m (1,640 ft) from one another.
3	Isolated distribution (likely to never, or only rarely, interbreed) and/or known from a single population center (narrow endemics); i.e., exists only in distinct, isolated, independent populations or metapopulations.

B.4.2.2 Population Abundance

Population abundance refers to the number of mature plants per population or meta-population. Species with lower population abundance are assigned higher scores because they are less resilient (and, therefore, more vulnerable) to catastrophic and stochastic events and chronic effects. They are more vulnerable because such events or effects are more likely to affect all individuals and because they are less capable of self-rescue from a population decline or population crash. Score this factor based on the abundance of the population with the lowest abundance out of the six most abundant populations. The score for this category is multiplied by two to weight the importance of this trait in overall species ecology.

[1] Gene flow between populations can rescue a population from extirpation by increasing its abundance (demographic rescue) or by increasing population fitness and evolutionary potential (genetic rescue).

Table B.4.5. Scoring guidelines for assessing a species' population abundance.

Score	Population Abundance
0	≥10,000 plants
1	5,000–10,000 plants
2	1,000–5,000 plants
3	<1,000 plants

B.4.2.3 Habitat Specificity

Habitat specificity describes the degree to which species are restricted to specific habitats (e.g., edaphic specialists). High habitat specificity is assigned a higher-ranking value to ensure the analysis area is more likely to encompass the specific habitat characteristics on which the species depends. The score for this category is multiplied by two to weight the importance of this trait in overall species ecology.

Table B.4.6. Scoring guidelines for assessing a species' habitat specificity.

Score	Habitat Specificity
0	Occurs on multiple habitat types with no apparent preferences for substrate types or microclimates.
1	Occurs in a specific substrate or microclimate that is not regionally rare.
2	Endemic to a substrate or microclimate that is regionally rare.
3	Endemic to a rare microhabitat within a regionally rare substrate or microclimate.

B.5 Rubric Results for Provisional HAA Groupings

Results and rationales for each species' HAA designation are summarized in the sections below. The characteristics considered in the HAA Rubric were evaluated based on information from the species summaries (see **Appendix A: Species Summaries for Federally Listed Plant Species in New Mexico**) and species experts. Species with a single known natural occurrence and species that are wetland obligates were not scored using the HAA Rubric. See Table 5.1 in **Recommendations for Endangered Species Act Section 7 Consultations Involving Plants in New Mexico** for compiled lists of species by HAA group and each group's associated HAA delineation distance value.

B.5.1 Argemone pinnatisecta

Table B.5.1. Provisional HAA grouping results for *Argemone pinnatisecta*.

Trait	Score (x)	Rationale
Breeding System	3	Outcrossing, not self-compatible or clonal.
Pollination	2	Wasps and bees (carpenter bees).
Seed Dispersal	2	Short distance surface run-off or wind (non-aerodynamic); ants.
Distribution Pattern	3	Geographically restricted to a single mountain range; occurrences in several drainages that are isolated from one another by topography.
Population Abundance	3 2x=6	Five occupied sites, ranging from 5–579 mature plants.
Habitat Specificity	2 2x=4	Found in various soils and habitats (canyon bottoms, slopes, roadsides), both mesic and arid. While not strictly a wetland species, association with areas of increased surface or soil moisture increases habitat vulnerability to climatic conditions and management that affects water availability.
Weighted Total	20	NA
Percent	83	NA
HAA Group	**3**	NA

B.5.2 *Sclerocactus mesae-verdae*

Table B.5.2. Provisional HAA grouping results for *Sclerocactus mesae-verdae*.

Trait	Score (x)	Rationale
Breeding System	2	Outcrossing and selfing (between two flowers on the same individual but not within one flower), but selfing results in significantly lower seed yields; vegetative asexual reproduction (potentially triggered by disturbance) from live and dislocated stems.
Pollination	3	Unknown what effectively pollinates, but visited by a variety of insects (sweat bees, beetles, Hymenoptera).
Seed Dispersal	3	Immediate vicinity dispersal; i.e., primarily dispersed by gravity or small, non-winged insects, such as ants.
Distribution Pattern	2	Narrow endemic; populations in many areas are close enough to allow for connectivity. In some locations, distances to next nearest plants are too far.
Population Abundance	3 2x=6	Unknown; smallest population likely less than 1,000 stems.
Habitat Specificity	1 2x=2	Endemic species growing on specific soils within a specific geological formation in the Four Corners area; geological formation not particularly rare.
Total	18	NA
Percent	75	NA
HAA Group	**2**	NA

B.5.3 *Echinocereus fendleri* var. *kuenzleri*

Table B.5.3. Provisional HAA grouping results for *Echinocereus fendleri* var. *kuenzleri*.

Trait	Score (x)	Rationale
Breeding System	3	Outcrossing, dichogamous; not self-compatible or clonal.
Pollination	2	Cactus bees likely most effective pollinators.
Seed Dispersal	0	Potential longer distances: rodents, birds, insects, surface run-off.
Distribution Pattern	3	Restricted patchy/random distribution; populations are isolated and only very rarely interbreed.
Population Abundance	3 2x=6	The largest current population extant (Fort Stanton) has a population size of 513 plants.
Habitat Specificity	1 2x=2	Specific, but not rare, habitat; skeletal soils of limestone origin.
Total	16	NA
Percent	67	NA
HAA Group	**1**	NA

B.5.4 Hedeoma todsenii

Table B.5.4. Provisional HAA grouping results for *Hedeoma todsenii*.

Trait	Score (x)	Rationale
Breeding System	0	Highly clonal; low sexual (outcrossing) reproduction.
Pollination	2	Wasps, primarily; rarely, broad-tailed hummingbirds.
Seed Dispersal	3	Immediate vicinity; fruits retain seeds and nutlets stick to soil near plant.
Distribution Pattern	3	Restricted; clumpy within; likely don't interbreed; significant barriers to gene flow (low sexual reproduction, poor seed viability).
Population Abundance	2 2x=4	The combined known locations in the Sacramento Mountains probably represent several hundred thousand to a few million plant clumps. In the San Andreas, at least 3000 clumps have been estimated.
Habitat Specificity	3 2x=6	Rare and specific habitat, a substrate of gypseous soils of the Permian Yeso formation, as well as sheltered areas amid piñon-juniper woodland with a north-facing aspect.
Total	18	NA
Percent	75	NA
HAA Group	**2**	NA

B.5.5 Astragalus humillimus

Table B.5.5. Provisional HAA grouping results for *Astragalus humillimus*.

Trait	Score (x)	Rationale
Breeding System	1	Mix of outcrossing and self-pollination; viable through both.
Pollination	2	Bees and butterflies.
Seed Dispersal	3	Immediate vicinity; surface run-off and wind (non-aerodynamic).
Distribution Pattern	3	Narrow endemic: follows cracks in bedrock. Distances between populations are often far.
Population Abundance	3 2x=6	Ute Mountain Ute Tribal Reservation 1987: estimated sum of individuals from 4 populations was 4,421. Navajo Nation 2019: estimated sum of individuals from 14 populations was 2,278. New Mexico 2020: Less than 400 plants in plots.
Habitat Specificity	3 2x=6	Endemic species growing in a specific niche within specific soils and geological formations in the Four Corners region.
Total	21	NA
Percent	88	NA
HAA Group	**3**	NA

B.5.6 Eriogonum gypsophilum

Table B.5.6. Provisional HAA grouping results for *Eriogonum gypsophilum*.

Trait	Score (x)	Rationale
Breeding System	2	Outcrossing/non-clonal; some selfing may occur, but likely results in reduced seed quality.
Pollination	2	Primarily wasps, bees, and flies.
Seed Dispersal	2	Ants; gravity, small mammals, and local dispersal of inflorescences containing ripe seed by wind.
Distribution Pattern	3	Restricted; populations are distinct and isolated and unlikely to interbreed; distance between populations creates a significant barrier to gene flow.
Population Abundance	1 2x=2	Populations of 6,000+ plants (6,000 min; 65,000 max).
Habitat Specificity	2 2x=4	Endemic to hypergypsic soils.
Total	15	NA
Percent	63	NA
HAA Group	**1**	NA

B.5.7 Erigeron rhizomatus

Table B.5.7. Provisional HAA grouping results for *Erigeron rhizomatus*.

Trait	Score (x)	Rationale
Breeding System	1	Mostly clonal via rhizomes and also sexual by seed dispersal (may be infrequent).
Pollination	3	No information, assumed to be generalists; bees, butterflies, beetles.
Seed Dispersal	0	Likely wind.
Distribution Pattern	3	Isolated, widely-dispersed subpopulations within 3 isolated metapopulations that are 64–113 kilometers (40–70 miles) apart.
Population Abundance	3 2x=6	165 to 2,195 plants per metapopulation.
Habitat Specificity	2 2x=4	Endemic on outcrops of shales of the Baca and Chinle formations.
Total	17	NA
Percent	71	NA
HAA Group	**2**	NA

B.5.8 Coryphantha sneedii var. *sneedii*

Table B.5.8. Provisional HAA grouping results for *Coryphantha sneedii* var. *sneedii*.

Trait	Score (x)	Rationale
Breeding System	2	Likely mixed mating system, clonal and sexual (unknown outcrossing versus selfing capabilities).
Pollination	2	Sweat bees.
Seed Dispersal	2	Insects, rodents, birds, surface run-off.
Distribution Pattern	3	Scattered and isolated populations (>100 miles between populations).
Population Abundance	3 2x=6	No data.
Habitat Specificity	1 2x=2	Limestone cracks on ledges or vertical cliffs.
Total	17	NA
Percent	71	NA
HAA Group	**2**	NA

B.5.9 Asplenium scolopendrum var. *americanum*

Table B.5.9. Provisional HAA grouping results for *Asplenium scolopendrum* var. *americanum*.

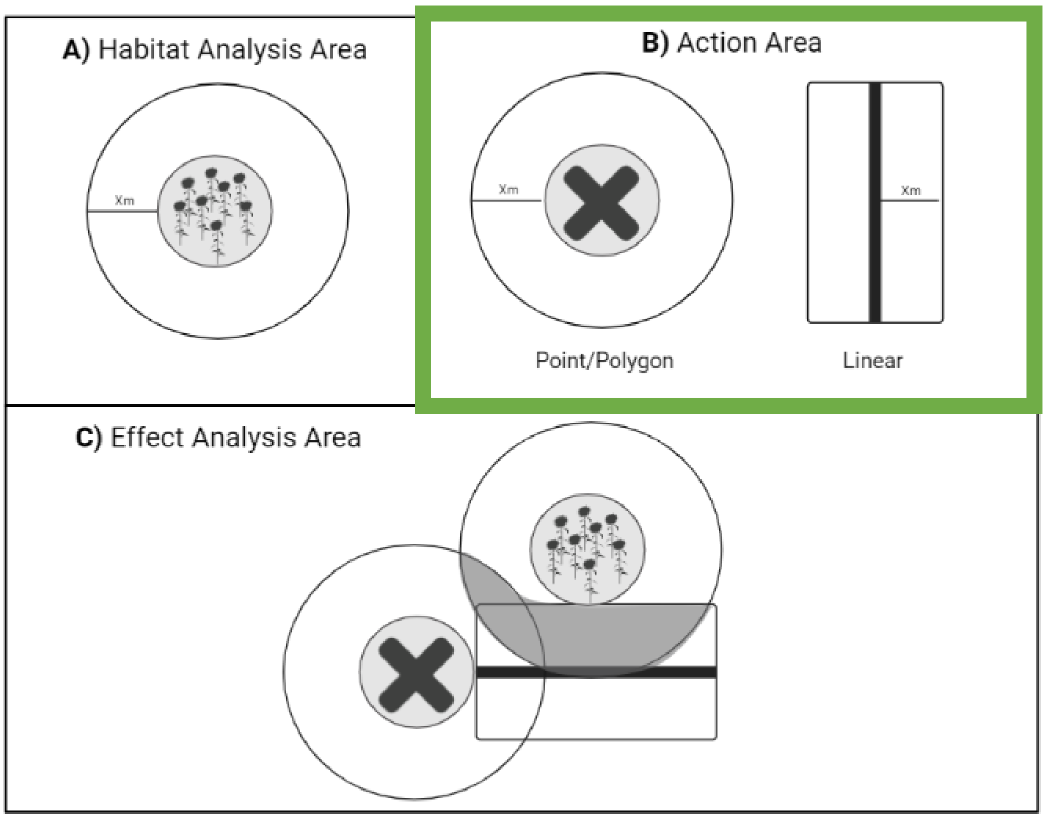
Trait	Score (x)	Rationale
Breeding System	1	More reliant on out-crossing compared to other ferns.
Pollination	0	Fertilization requires a film of water for the sperm to reach and fertilize the egg; thus, moisture is necessary for successful sexual reproduction.
Seed Dispersal	0	Not well studied; primary airborne transport for most terrestrial ferns. However, habitats with cliffs, sinkholes, and ravines limit spore dispersal distance. Additional mechanisms are possible, including short-distance dispersal following ingestion by slugs and snails, and attachment to mammals.
Distribution Pattern	1.5	Distribution is on a continental scale with disjunct populations. Distinct populations have been operationally considered as those separated from other individuals by at least 20 m (65 ft), based on the best available genetic information and analysis of potential for gene flow.
Population Abundance	3 2x=6	Some populations are small and isolated, others large and continuous; population in New Mexico is small and isolated, estimated at about 66 individuals.
Habitat Specificity	3 2x=6	Karst topography, found in escarpments and sinkholes; lava caves in New Mexico.
Total	14.5	NA
Percent	60	NA
HAA Group	**1**	NA

B.6 References

National Hydrography. n.d. Watershed Boundary Dataset. *U.S. Geological Survey*. https://www.usgs.gov/national-hydrography/watershed-boundary-dataset, accessed December 29, 2023.

National Hydrography. 2018. Watershed Boundary Dataset structure visualization. *U.S. Geological Survey: Images*. https://www.usgs.gov/media/images/watershed-boundary-dataset-structure-visualization, accessed December 29, 2023.

Appendix C Literature Reviewed for Action Area Considerations



Prepared By:

Institute for Applied Ecology

For:

U.S. Fish and Wildlife Service

New Mexico Ecological Services Field Office

May 2024

Table of Contents

List of Tables

C.1 Tables of Studies Reviewed

The following tables list and summarize literature reviewed to support section ***5.4 Action Area Considerations*** of **Recommendations for Endangered Species Act Section 7 Consultations Involving Plants in New Mexico**. Documents reviewed include peer-reviewed journal articles and agency technical reports.

Table C.1. Studies reviewed looking at general effects of various project actions (supporting section 5.4.1 General Effects of Various Actions). Lists of potential sources of these effects are not inclusive.

General Effect	Related Effects	Potential Sources	References
Atmospheric Particulate Matter/Dust	• reduced plant growth • shifts in plant community composition • altered soil chemistry, nutrient loss • reduced plant reproduction • altered plant physiology (changes in photosynthetic rates, reduced water use efficiency, reduced leaf conductance)	• any land clearing activities • roads and vehicle trails • non-motorized trails • oil and gas development • agriculture • mineral extraction	• Farmer (1993) • Gleason et al. (2007) • Kameswaran et al. (2019) • Li et al. (2007) • McCrea (1984) • Wijayratne et al. (2009) • Sharifi et al. (1997)
Soil Compaction	• reduced seedling emergence and establishment • altered hydrology (increased run-off speed and deceased water infiltration) • increased soil erosion • reduced soil seed bank densities • restricted root growth • reduced soil nutrients	• roads and vehicle trails • non-motorized trails • oil and gas development • agriculture • livestock trampling • mineral extraction	• Allington and Valone (2010) • Castellano and Valone (2007) • DeFalco et al. (2009) • Hettiaratchi (1990) • Nawaz et al. (2013) • Singh et al. (2015) • Stoessel et al. (2018)
Land Clearing and Erosion	• mortality • habitat fragmentation and edge effects (see table C.4) • altered hydrology (increased run-off speed and decreased water infiltration) • increased soil erosion • reduced soil nutrients	• any land clearing activities • road construction • well pad installation • agricultural development	• Cowie et al. (2007) • Hunter et al. (1987) • Neldner et al. (2017) • Ravi et al. (2010)

General Effect	Related Effects	Potential Sources	References
Invasive Species	• reduced native species abundance • reduced performance of native species • increased competition • altered disturbance regimes	• linear infrastructure • livestock • vehicle and machinery operation • foot traffic	• Dueñas et al. (2018) • Dueñas et al. (2021) • Gurevitch and Padilla (2004) • Thomson (2005) • Walker and Smith (1997)
Water Diversion, Extraction, and Impoundment	• decreased plant diversity • reduced plant performance (biomass, flowering, leaf size, etc.) • loss of wetland or riparian obligate plant species	• groundwater pumping • oil and gas development • mineral extraction • agriculture • livestock operations • residential development • hydropower	• Elmore et al. (2006) • Hasselquist and Allen (2009) • Jolly et al. (2008) • Stromberg et al. (1996) • K. Zhang et al. (2019) • W. Zhang et al. (2019)
Ambient Pollution	• altered species composition • physiological changes • decreased species richness • decreased plant performance (biomass, flowering, etc.)	• vehicle traffic • oil and gas development • mineral extraction • fire	• Ryabuhina et al. (2019) • Brooks (2003) • Honour et al. (2009) • Joshi and Swami (2009) • Lovett et al. (2009)
Herbicide Treatments	• inhibited plant reproduction (delayed flowering, reduced flowering, reduced seed set) • plant mortality • reduced growth • pollinator mortality	• rights-of-way maintenance • oil and gas development • conservation applications	• Boutin et al. (2014) • Erickson et al. (2006) • Davis and Williams (1990) • Matarczyk et al. (2002)

Table C.2. Studies reviewed looking at effects of activities and disturbances from linear infrastructure (supporting section **5.4.2.1 Linear Infrastructure**).

Source	General Effect	Related Effects	Observed Effect Distance Range (m)	References
Roads	Altered vegetation community	• shifts in composition • reduced species richness and diversity	100–1,000	• Angold (1997) • Brosofske et al. (1999) • Findlay and Houlahan (1997) • Lee et al. (2012) • Myers-Smith et al. (2006) • Zechmeister et al. (2005)
Roads	Fugitive dust	• altered soil chemistry • altered plant community composition • reduced cryptograms	100–700	• Ackerman and Findlay (2019) • Auerbach et al. (1997) • Etyemezian et al. (2004) • Lewis et al. (2017) • Padgett et al. (2008) • Walker and Everett (1987)
Roads	Invasive species	• reduced native species abundance • increased competition • altered disturbance regimes	10–1,000	• Assaeed et al. (2019) • Bradley and Mustard (2006) • Brisson et al. (2010) • Christen and Matlack (2009) • Flory and Clay (2006) • Gelbard and Belnap (2003) • Gelbard and Harrison (2003) • Hansen and Clevenger (2005) • Johnston and Johnston (2004)
Roads	Restricted animal movement	• reduced genetic connectivity for animal pollinated or dispersed plant species	NA	• Forman (2000)
Roads	Soil compaction	• reduced seedling emergence and establishment • altered hydrology • increased soil erosion	≤ 1,000	• Adams et al. (1982) • Forman and Alexander (1998) • Raiter et al. (2018)

Source	General Effect	Related Effects	Observed Effect Distance Range (m)	References
Roads	Altered plant physiology	• nitrogen enrichment • membrane leakage • increased chlorophyll concentration	100	• Bignal et al. (2008)
Trails	Altered hydrology	• increased erosion • soil compaction	NA	• White et al. (2006)
Trails	Invasive species	• reduced native species abundance • increased competition • altered disturbance regimes	100	• Tyser and Worley (1992)
Trails	Altered vegetation community	• reduced cover due to trampling and clearing • shifts in composition	20	• Ballantyne and Pickering (2015) • Cole (1986)
Trails	Pollinator disruptions	• reduced plant reproduction	25	• Huang et al. (2009)
Transmission Lines/Utility Corridors	Increased wildfire risk	• unspecified	NA	• Mitchell (2009)
Transmission Lines/Utility Corridors	Invasive species	• reduced native species abundance • increased competition • altered disturbance regimes	NA	• Beley et al. (1982) • Biasotto and Kindel (2018) • Çoban et al. (2019)
Transmission Lines/Utility Corridors	Altered animal movement and habitat usage	• reduced genetic connectivity for animal pollinated or dispersed plant species	NA	• Richardson et al. (2017)
Pipelines	Altered vegetation community	• shifts in composition • reduced plant diversity • lowered productivity (biomass)	500	• Desserud and Naeth (2013) • Lathrop and Archbold (1980a) • Lathrop and Archbold (1980b) • Xiao et al. (2014)

Source	General Effect	Related Effects	Observed Effect Distance Range (m)	References
Pipelines	Altered soil characteristics	• compaction • reduced water retention and infiltration • altered chemical properties • altered soil structure	NA	• Olson and Doherty (2012) • Soon et al. (2000)
Pipelines	Invasive species	• reduced native species abundance • increased competition • altered disturbance regimes	NA	• Xiao et al. (2014)

Table C.3. Studies reviewed looking at effects from oil and gas related activities and disturbances (supporting section **5.4.2.2 Oil and Gas Operations**).

General Effect	Related Effect(s)	Observed Effect Distance Range (m)	References
Altered Ambient Conditions	• reduced plant growth	100	• Dung et al. (2008)
Habitat Conversion/Fragmentation	• see Table C.4, "Habitat Fragmentation"	NA	• Jones and Pejchar (2013) • Jones et al. (2014) • Ochege et al. (2017) • Pierre et al. (2018)
Soil Contamination	• reduced plant germination and survival • reduced vegetation cover and richness • reduced plant growth • plant mortality or damage	NA	• Balasubramaniyam and Harvey (2014) • Baruah et al. (2014) • Hawrot-Paw et al. (2015) • Otton et al. (2005) • Pichtel (2016) • Shapiro et al. (2016)
Ambient Pollution	• plant mortality or damage • see Table C.1, "Ambient Pollution"	NA	• Isichei (2014)

Table C.4. Studies reviewed looking at effects of habitat fragmentation on plants (supporting section **5.4.1.8 Habitat Fragmentation**).

Primary Effect	Related Effects	References
Disrupted Gene Flow/Reduced Genetic Diversity	• reduced population persistence and viability • decreased population size • increased genetic differentiation across populations • reduced outcrossing and increased inbreeding depression and outbreeding depression potential • reduced plant reproduction (pollination and seed set)	• Aguilar et al. (2008) • Aguilar et al. (2019) • Aizen and Feinsinger (1994a) • Culley and Grubb (2003) • Cunningham (2000) • Duncan et al. (2004) • Ellstrand and Elam (1993) • Hensen and Oberprieler (2005) • Hevroy et al. (2017) • Honnay et al. (2005) • Honnay et al. (2007) • Honnay and Jacquemyn (2007) • Hooftman et al. (2004) • Kwak et al. (1998) • Menges (1991) • Morgan (1999) • Wolf et al. (2000)
Pollinator Declines	• reduced plant reproduction (pollination and seed set) • changes in flower-visitor assemblages (declines in the frequency and diversity of native pollinators)	• Aizen and Feinsinger (1994a) • Aizen and Feinsinger (1994b) • Rathcke and Jules (1993) • Steffan-Dewenter and Tscharntke (1999)

C.2 Literature Cited

Ackerman, D. E., and J. C. Finlay. 2019. Road dust biases NDVI and alters edaphic properties in Alaskan arctic tundra. *Scientific Reports* 9: 1–8.

Adams, J. A., A. S. Endo, L. H. Stolzy, P. G. Rowlands, and H. B. Johnson. 1982. Controlled experiments on soil compaction produced by off-road vehicles in the Mojave Desert, California. *Journal of Applied Ecology* 19: 167–175.

Aguilar, R., M. Quesada, L. Ashworth, Y. Herrerias-Diego, and J. Lobo. 2008. Genetic consequences of habitat fragmentation in plant populations: Susceptible signals in plant traits and methodological approaches. *Molecular Ecology* 17: 5177–5188.

Aguilar, R., E. J. Cristóbal-Pérez, F. J. Balvino-Olvera, M. Aguilar-Aguilar, N. Aguirre-Acosta, L. Ashworth, J. A. Lobo, S. Martén-Rodríguez, et al. 2019. Habitat fragmentation reduces plant progeny quality: A global synthesis. *Ecology Letters* 22: 1163–1173.

Aizen, M. A., and P. Feinsinger. 1994a. Forest fragmentation, pollination, and plant reproduction in a Chaco dry forest, Argentina. *Ecology* 75: 330–351.

Aizen, M. A., and P. Feinsinger. 1994b. Habitat fragmentation, native insect pollinators, and feral honey bees in Argentine 'Chaco Serrano.' *Ecological Applications* 4: 378–392.

Allington, G. R. H., and T. J. Valone. 2010. Reversal of desertification: The role of physical and chemical soil properties. *Journal of Arid Environments* 74: 973–977.

Angold, P. G. 1997. The impact of a road upon adjacent heathland vegetation: Effects on plant species composition. *The Journal of Applied Ecology* 34: 409–417.

Assaeed, A. M., S. L. Al-Rowaily, M. I. El-Bana, A. A. Abood, B. A. Dar, and A. K. Hegazy. 2019. Impact of off-road vehicles on soil and vegetation in a desert rangeland in Saudi Arabia. *Saudi Journal of Biological Sciences* 26: 1187–1193.

Auerbach, N. A., M. D. Walker, and D. A. Walker. 1997. Effects of roadside disturbance on substrate and vegetation properties in arctic tundra. *Ecological Applications* 7: 218–235.

Balasubramaniyam, A., and P. J. Harvey. 2014. Scanning electron microscopic investigations of root structural modifications arising from growth in crude oil-contaminated sand. *Environmental Science and Pollution Research* 21: 12651–12661.

Ballantyne, M., and C. M. Pickering. 2015. The impacts of trail infrastructure on vegetation and soils: Current literature and future directions. *Journal of Environmental Management* 164: 53–64.

Baruah, P., R. R. Saikia, P. P. Baruah, and S. Deka. 2014. Effect of crude oil contamination on the chlorophyll content and morpho-anatomy of Cyperus brevifolius (Rottb.) Hassk. *Environmental Science and Pollution Research* 21: 12530–12538.

Beley, J. R., T. M. Ditsworth, S. M. Butt, and C. D. Johnson. 1982. Arthropods, plants and transmission lines in Arizona: Community dynamics during secondary succession in a pinyon-juniper chaparral habitat. *The Southwestern Naturalist* 27: 325.

Biasotto, L. D., and A. Kindel. 2018. Power lines and impacts on biodiversity: A systematic review. *Environmental Impact Assessment Review* 71: 110–119.

Bignal, K. L., M. R. Ashmore, and A. D. Headley. 2008. Effects of air pollution from road transport on growth and physiology of six transplanted bryophyte species. *Environmental Pollution* 156: 332–340.

Boutin, C., B. Strandberg, D. Carpenter, S. K. Mathiassen, and P. J. Thomas. 2014. Herbicide impact on non-target plant reproduction: What are the toxicological and ecological implications? *Environmental Pollution* 185: 295–306.

Bradley, B. A., and J. F. Mustard. 2006. Characterizing the landscape dynamics of an invasive plant and risk of invasion using remote sensing. *Ecological Applications* 16: 1132–1147.

Brisson, J., S. de Blois, and C. Lavoie. 2010. Roadside as invasion pathway for common reed (Phragmites australis). *Invasive Plant Science and Management* 3: 506–514.

Brooks, M. L. 2003. Effects of increased soil nitrogen on the dominance of alien annual plants in the Mojave Desert. *Journal of Applied Ecology* 40: 344–353.

Brosofske, K. D., J. Chen, T. R. Crow, and S. C. Saunders. 1999. Vegetation responses to landscape structure at multiple scales across a Northern Wisconsin, USA, pine barrens landscape. *Plant Ecology* 143: 203–218.

Castellano, M. J., and T. J. Valone. 2007. Livestock, soil compaction and water infiltration rate: Evaluating a potential desertification recovery mechanism. *Journal of Arid Environments* 71: 97–108.

Christen, D. C., and G. R. Matlack. 2009. The habitat and conduit functions of roads in the spread of three invasive plant species. *Biological Invasions* 11: 453–465.

Çoban, S., S. Balekoğlu, and G. Özalp. 2019. Change in plant species composition on powerline corridor: A case study. *Environmental Monitoring and Assessment* 191: (Article 200) 1-13.

Cole, D. N. 1986. *Resource impacts caused by recreation: A literature review*. INT4901 Publication #165. Missoula, Montana: The President's Commission on American Outdoors.

Cowie, B. A., C. M. Thornton, and B. J. Radford. 2007. The Brigalow Catchment Study: I. Overview of a 40-year study of the effects of land clearing in the Brigalow bioregion of Australia. *Soil Research* 45: 479–495.

Culley, T. M., and T. C. Grubb. 2003. Genetic effects of habitat fragmentation in Viola pubescens (Violaceae), a perennial herb with chasmogamous and cleistogamous flowers. *Molecular Ecology* 12: 2919–2930.

Cunningham, S. A. 2000. Depressed pollination in habitat fragments causes low fruit set. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 267: 1149–1152.

Davis, B. N. K., and C. T. Williams. 1990. Buffer zone widths for honeybees from ground and aerial spraying of insecticides. *Environmental Pollution* 63: 247–259.

DeFalco, L. A., T. C. Esque, J. M. Kane, and M. B. Nicklas. 2009. Seed banks in a degraded desert shrubland: Influence of soil surface condition and harvester ant activity on seed abundance. *Journal of Arid Environments* 73: 885–893.

Desserud, P. A., and M. A. Naeth. 2013. Natural recovery of rough fescue (Festuca hallii (Vasey) Piper) grassland after disturbance by pipeline construction in central Alberta, Canada. *Natural Areas Journal* 33: 91–98.

Dueñas, M.-A., H. J. Ruffhead, N. H. Wakefield, P. D. Roberts, D. J. Hemming, and H. Diaz-Soltero. 2018. The role played by invasive species in interactions with endangered and threatened species in the United States: A systematic review. *Biodiversity and Conservation* 27: 3171–3183.

Dueñas, M.-A., D. J. Hemming, A. Roberts, and H. Diaz-Soltero. 2021. The threat of invasive species to IUCN-listed critically endangered species: A systematic review. *Global Ecology and Conservation* 26: e01476.

Duncan, D. H., A. B. Nicotra, J. T. Wood, and S. A. Cunningham. 2004. Plant isolation reduces outcross pollen receipt in a partially self-compatible herb. *Journal of Ecology* 92: 977–985.

Dung, E. J., L. S. Bombom, and T. D. Agusomu. 2008. The effects of gas flaring on crops in the Niger Delta, Nigeria. *GeoJournal* 73: 297–305.

Ellstrand, N. C., and D. R. Elam. 1993. Population genetic consequences of small population size: Implications for plant conservation. *Annual Review of Ecology and Systematics* 24: 217–242.

Elmore, A. J., S. J. Manning, J. F. Mustard, and J. M. Craine. 2006. Decline in alkali meadow vegetation cover in California: The effects of groundwater extraction and drought. *Journal of Applied Ecology* 43: 770–779.

Erickson, A. M., R. G. Lym, and D. Kirby. 2006. Effect of herbicides for leafy spurge control on the western prairie fringed orchid. *Rangeland Ecology & Management* 59: 462–467.

Etyemezian, V., S. Ahonen, D. Nikolic, J. Gillies, H. Kuhns, D. Gillette, and J. Veranth. 2004. Deposition and removal of fugitive dust in the arid southwestern United States: Measurements and model results. *Journal of the Air & Waste Management Association* 54: 1099–1111.

Farmer, A. M. 1993. The effects of dust on vegetation: A review. *Environmental Pollution* 79: 63–75.

Findlay, C. S., and J. Houlahan. 1997. Anthropogenic correlates of species richness in southeastern Ontario wetlands. *Conservation Biology* 11: 1000–1009.

Flory, S. L., and K. Clay. 2006. Invasive shrub distribution varies with distance to roads and stand age in eastern deciduous forests in Indiana, USA. *Plant Ecology* 184: 131–141.

Forman, R. T. T. 2000. Estimate of the area affected ecologically by the road system in the United States. *Conservation Biology* 14: 31–35.

Forman, R. T. T., and L. E. Alexander. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* 29: 207–231.

Gelbard, J. L., and J. Belnap. 2003. Roads as conduits for exotic plant invasions in a semiarid landscape. *Conservation Biology* 17: 420–432.

Gelbard, J. L., and S. Harrison. 2003. Roadless habitats as refuges for native grasslands: Interactions with soil, aspect, and grazing. *Ecological Applications* 13: 404–415.

Gleason, S. M., D. T. Faucette, M. M. Toyofuku, C. A. Torres, and C. F. Bagley. 2007. Assessing and mitigating the effects of windblown soil on rare and common vegetation. *Environmental Management* 40: 1016–1024.

Gurevitch, J., and D. Padilla. 2004. Are invasive species a major cause of extinctions? *Trends in Ecology & Evolution* 19: 470–474.

Hansen, M. J., and A. P. Clevenger. 2005. The influence of disturbance and habitat on the presence of non-native plant species along transport corridors. *Biological Conservation* 125: 249–259.

Hasselquist, N. J., and M. F. Allen. 2009. Increasing demands on limited water resources: Consequences for two endangered plants in Amargosa Valley, USA. *American Journal of Botany* 96: 620–626.

Hawrot-Paw, M., A. Wijatkowski, and M. Mikiciuk. 2015. Influence of diesel and biodiesel fuel-contaminated soil on microorganisms, growth and development of plants. *Plant, Soil and Environment* 61: 189–194.

Hensen, I., and C. Oberprieler. 2005. Effects of population size on genetic diversity and seed production in the rare Dictamnus albus (Rutaceae) in central Germany. *Conservation Genetics* 6: 63–73.

Hettiaratchi, D. R. P. 1990. Soil compaction and plant root growth. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 329: 343–355.

Hevroy, T. H., M. L. Moody, and S. L. Krauss. 2017. Population genetic analysis reveals barriers and corridors for gene flow within and among riparian populations of a rare plant. *AoB PLANTS* 10: (Article plx065) 1-12.

Honnay, O., and H. Jacquemyn. 2007. Susceptibility of common and rare plant species to the genetic consequences of habitat fragmentation. *Conservation Biology* 21: 823–831.

Honnay, O., H. Jacquemyn, B. Bossuyt, and M. Hermy. 2005. Forest fragmentation effects on patch occupancy and population viability of herbaceous plant species. *New Phytologist* 166: 723–736.

Honnay, O., D. Adriaens, E. Coart, H. Jacquemyn, and I. Roldan-Ruiz. 2007. Genetic diversity within and between remnant populations of the endangered calcareous grassland plant Globularia bisnagarica L. *Conservation Genetics* 8: 293–303.

Honour, S. L., J. N. B. Bell, T. W. Ashenden, J. N. Cape, and S. A. Power. 2009. Responses of herbaceous plants to urban air pollution: Effects on growth, phenology and leaf surface characteristics. *Environmental Pollution* 157: 1279–1286.

Hooftman, D. A. P., R. C. Billeter, B. Schmid, and M. Diemer. 2004. Genetic effects of habitat fragmentation on common species of Swiss fen meadows. *Conservation Biology* 18: 1043–1051.

Huang, B.-Q., Y.-N. Sun, X.-H. Yu, Y.-B. Luo, M. J. Hutchings, and S.-Y. Tang. 2009. Impact of proximity to a pathway on orchid pollination success in Huanglong National Park, South-West China. *Biological Conservation* 142: 701–708.

Hunter, R., F. B. Turner, R. G. Lindberg, and K. B. Hunter. 1987. Effects of land clearing on bordering winter annual populations in the Mohave Desert. *The Great Basin Naturalist* 47: 234–238.

Isichei, A. O. 2014. Effects of oil industry operations on vegetation in Nigeria. In *Environmental Monitoring and Impact Assessment*, ed. A. F. Oluwole, Asublojo, I. B. Obioh, and O. J. Ogunsola, 258–269. Lagos, Nigeria: Seems Nig. Ltd.

Johnston, F. M., and S. W. Johnston. 2004. Impacts of road disturbance on soil properties and on exotic plant occurrence in subalpine areas of the Australian Alps. *Arctic, Antarctic, and Alpine Research* 36: 201–207.

Jolly, I. D., K. L. McEwan, and K. L. Holland. 2008. A review of groundwater-surface water interactions in arid/semi-arid wetlands and the consequences of salinity for wetland ecology. *Ecohydrology* 1: 43–58.

Jones, I. L., J. W. Bull, E. J. Milner-Gulland, A. V. Esipov, and K. B. Suttle. 2014. Quantifying habitat impacts of natural gas infrastructure to facilitate biodiversity offsetting. *Ecology and Evolution* 4: 79–90.

Jones, N. F., and L. Pejchar. 2013. Comparing the ecological impacts of wind and oil & gas development: A landscape scale assessment. *PLOS ONE* 8: (Article e81391) 1-12.

Joshi, P. C., and A. Swami. 2009. Air pollution induced changes in the photosynthetic pigments of selected plant species. *Journal of Environmental Biology* 30: 295–298.

Kameswaran, S., Y. Gunavathi, and P. G. Krishna. 2019. Dust pollution and its influence on vegetation: A critical analysis. *Research Journal of Life Sciences, Bioinformatics, Pharmaceutical and Chemical Sciences* 5: 341–363.

Kwak, M. M., O. Velterop, and J. Van Andel. 1998. Pollen and gene flow in fragmented habitats. *Applied Vegetation Science* 1: 37–54.

Lathrop, E. W., and E. F. Archbold. 1980a. Plant response to Los Angeles aqueduct construction in the Mojave desert. *Environmental Management* 4: 137–148.

Lathrop, E. W., and E. F. Archbold. 1980b. Plant response to utility right of way construction in the Mojave Desert. *Environmental Management* 4: 215–226.

Lee, M. A., L. Davies, and S. A. Power. 2012. Effects of roads on adjacent plant community composition and ecosystem function: An example from three calcareous ecosystems. *Environmental Pollution* 163: 273–280.

Lewis, M. B., E. W. Schupp, and T. A. Monaco. 2017. Road dust correlated with decreased reproduction of the endangered Utah shrub Hesperidanthus suffrutescens. *Western North American Naturalist* 77: 430–439.

Li, J., G. S. Okin, L. Alvarez, and H. Epstein. 2007. Quantitative effects of vegetation cover on wind erosion and soil nutrient loss in a desert grassland of southern New Mexico, USA. *Biogeochemistry* 85: 317–332.

Lovett, G. M., T. H. Tear, D. C. Evers, S. E. G. Findlay, B. J. Cosby, J. K. Dunscomb, C. T. Driscoll, and K. C. Weathers. 2009. Effects of air pollution on ecosystems and biological diversity in the eastern United States. *Annals of the New York Academy of Sciences* 1162: 99–135.

Matarczyk, J. A., A. J. Willis, J. A. Vranjic, and J. E. Ash. 2002. Herbicides, weeds and endangered species: Management of Bitou bush (Chrysanthemoides monilifera ssp. rotundata) with glyphosate and impacts on the endangered shrub, Pimelea spicata. *Biological Conservation* 108: 133–141.

McCrea, P. R. 1984. *An assessment of the effects of road dust on agricultural production systems*. Research Report 156. Canterbury, New Zealand: Lincoln College, Agricultural Economics Research Unit.

Menges, E. S. 1991. Seed germination percentage increases with population size in a fragmented prairie species. *Conservation Biology* 5: 158–164.

Mitchell, J. 2009. Power lines and catastrophic wildland fire in Southern California. In *Conference Proceedings, 11th International Conference and Exhibition: 26-28 January, 2009, Fisherman's Wharf, San Francisco, USA*. United Kingdom: Interscience Communications.

Morgan, J. W. 1999. Effects of population size on seed production and germinability in an endangered, fragmented grassland plant. *Conservation Biology* 13: 266–273.

Myers-Smith, I. H., B. K. Arnesen, R. M. Thompson, and F. S. Chapin. 2006. Cumulative impacts on Alaskan arctic tundra of a quarter century of road dust. *Ecoscience* 13: 503–510.

Nawaz, M. F., G. Bourrié, and F. Trolard. 2013. Soil compaction impact and modelling: A review. *Agronomy for Sustainable Development* 33: 291–309.

Neldner, V. J., M. J. Laidlaw, K. R. McDonald, M. T. Mathieson, R. I. Melzer, R. Seaton, W. J. F. McDonald, R. Hobson, et al. 2017. *Scientific review of the impacts of land clearing on threatened species in Queensland*. Brisbane, Queensland, Australia: Queensland Government.

Ochege, F. U., R. T. George, E. C. Dike, and C. Okpala-Okaka. 2017. Geospatial assessment of vegetation status in Sagbama oilfield environment in the Niger Delta region, Nigeria. *The Egyptian Journal of Remote Sensing and Space Science* 20: 211–221.

Olson, E. R., and J. M. Doherty. 2012. The legacy of pipeline installation on the soil and vegetation of southeast Wisconsin wetlands. *Ecological Engineering* 39: 53–62.

Otton, J. K., R. A. Zielinski, B. D. Smith, M. M. Abbott, and B. D. Keeland. 2005. Environmental impacts of oil production on soil, bedrock, and vegetation at the U.S. Geological Survey Osage–Skiatook Petroleum Environmental Research site A, Osage County, Oklahoma. *Environmental Geosciences* 12: 73–87.

Padgett, P. E., D. Meadows, E. Eubanks, and W. E. Ryan. 2008. Monitoring fugitive dust emissions from off-highway vehicles traveling on unpaved roads and trails using passive samplers. *Environmental Monitoring and Assessment* 144: 93–103.

Pichtel, J. 2016. Oil and gas production wastewater: Soil contamination and pollution prevention. *Applied and Environmental Soil Science* 2016: 1–24.

Pierre, J. P., B. D. Wolaver, B. J. Labay, T. J. LaDuc, C. M. Duran, W. A. Ryberg, T. J. Hibbitts, and J. R. Andrews. 2018. Comparison of recent oil and gas, wind energy, and other anthropogenic landscape alteration factors in Texas through 2014. *Environmental Management* 61: 805–818.

Raiter, K. G., S. M. Prober, H. P. Possingham, F. Westcott, and R. J. Hobbs. 2018. Linear infrastructure impacts on landscape hydrology. *Journal of Environmental Management* 206: 446–457.

Rathcke, B. J., and E. S. Jules. 1993. Habitat fragmentation and plant–pollinator interactions. *Current Science* 65: 273–277.

Ravi, S., D. D. Breshears, T. E. Huxman, and P. D’Odorico. 2010. Land degradation in drylands: Interactions among hydrologic–aeolian erosion and vegetation dynamics. *Geomorphology* 116: 236–245.

Richardson, M. L., B. A. Wilson, D. A. S. Aiuto, J. E. Crosby, A. Alonso, F. Dallmeier, and G. K. Golinski. 2017. A review of the impact of pipelines and power lines on biodiversity and strategies for mitigation. *Biodiversity and Conservation* 26: 1801–1815.

Ryabuhina, M. V., R. A. Maiski, and R. G. Kalyakina. 2019. Transboundary air pollution and its effects on vegetation. *IOP Conference Series: Materials Science and Engineering* 687: (Article 066043) 1-7.

Shapiro, K., S. Khanna, and S. Ustin. 2016. Vegetation impact and recovery from oil-induced stress on three ecologically distinct wetland sites in the Gulf of Mexico. *Journal of Marine Science and Engineering* 4: (Article 33) 1-19.

Sharifi, M. R., A. C. Gibson, and P. W. Rundel. 1997. Surface dust impacts on gas exchange in Mojave Desert shrubs. *The Journal of Applied Ecology* 34: 837–846.

Singh, J., A. Salaria, and A. Kaul. 2015. Impact of soil compaction on soil physical properties and root growth: A review. *International Journal of Food, Agriculture and Veterinary Sciences* 5: 23–32.

Soon, Y. K., M. A. Arshad, W. A. Rice, and P. Mills. 2000. Recovery of chemical and physical properties of boreal plain soils impacted by pipeline burial. *Canadian Journal of Soil Science* 80: 489–497.

Steffan-Dewenter, I., and T. Tscharntke. 1999. Effects of habitat isolation on pollinator communities and seed set. *Oecologia* 121: 432–440.

Stoessel, F., T. Sonderegger, P. Bayer, and S. Hellweg. 2018. Assessing the environmental impacts of soil compaction in life cycle assessment. *Science of The Total Environment* 630: 913–921.

Stromberg, J. C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. *Ecological Applications* 6: 113–131.

Thomson, D. 2005. Measuring the effects of invasive species on the demography of a rare endemic plant. *Biological Invasions* 7: 615–624.

Tyser, R. W., and C. A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park, Montana (U.S.A.). *Conservation Biology* 6: 253–262.

Walker, D. A., and K. R. Everett. 1987. Road dust and its environmental impact on Alaskan taiga and tundra. *Arctic and Alpine Research* 19: 479–489.

Walker, L. R., and S. D. Smith. 1997. Impacts of invasive plants on community and ecosystem properties. In *Assessment and Management of Plant Invasions*, ed. J. O. Luken and J. W. Thieret, 69–86. Springer Series on Environmental Management. New York, New York: Springer.

White, D. D., M. T. Waskey, G. P. Brodehl, and P. E. Foti. 2006. A comparative study of impacts to mountain bike trails in five common ecological regions of the southwestern U.S. *Journal of Park and Recreation Administration* 24: 21–41.

Wijayratne, U. C., S. J. Scoles-Sciulla, and L. A. Defalco. 2009. Dust deposition effects on growth and physiology of the endangered Astragalus jaegerianus (Fabaceae). *Madroño* 56: 81–88.

Wolf, A. T., S. P. Harrison, and J. L. Hamrick. 2000. Influence of habitat patchiness on genetic diversity and spatial structure of a serpentine endemic plant. *Conservation Biology* 14: 454–463.

Xiao, J., Y.-F. Wang, P. Shi, L. Yang, and L.-D. Chen. 2014. Potential effects of large linear pipeline construction on soil and vegetation in ecologically fragile regions. *Environmental Monitoring and Assessment* 186: 8037–8048.

Zechmeister, H. G., D. Hohenwallner, A. Riss, and A. Hanus-Illnar. 2005. Estimation of element deposition derived from road traffic sources by using mosses. *Environmental Pollution* 138: 238–249.

Zhang, K., Y. Shi, X. Cui, P. Yue, K. Li, X. Liu, B. M. Tripathi, and H. Chu. 2019. Salinity is a key determinant for soil microbial communities in a desert ecosystem. *mSystems* 4: (Article e00225-18) 1-11.

Zhang, W., C. Wang, R. Xue, and L. Wang. 2019. Effects of salinity on the soil microbial community and soil fertility. *Journal of Integrative Agriculture* 18: 1360–1368.