Evaluating Potential Threats to Wyoming

Threatened, Endangered and Sensitive Plant Species

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ABSTRACT

We evaluated the exposure of 194 plant species of conservation and management concern to energy development activities in Wyoming. This included 39 BLM Special Status Species (SSS) plants and 155 other Wyoming plant species of concern (SOC) or potential concern (PSOC) known from BLM lands. The majority of species (76.3%) had negligible or no exposure levels (<1%) to either oil & gas or wind energy development at current or projected levels. Of the five SSS species and 41 other species with exposure levels greater than 1% to either type of energy development, 41 (21.1%) were exposed to oil & gas development, seven (3.6%) were exposed to wind development, and only two (1.0%) were exposed to both oil/gas and wind development. Fifteen species were flagged as having moderate or high exposure levels (greater than 15% exposure to oil & gas development at current or projected levels) while only one species, Laramie false sagebrush (*Sphaeromeria simplex*), had greater than 5% exposure to wind development at projected levels.

GIS output is presented for reference, and integrated with secondary source information into state species abstract text for the relevant plant species. A simplified GIS comparison was conducted by interpreting distribution overlaps with coal leases and potential uranium resources in which eight species (4.1%) overlapped with current coal leases and 42 species (21.6%) overlapped with all uranium resources.

<u>Citation</u>:

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ACKNOWLEDGEMENTS

Energy development layers built by Doug Keinath (Wyoming Natural Diversity Database; WYNDD) were used in this analysis as originally prepared for the Assessment of Wildlife Vulnerability to Energy Development (Keinath et al. 2008). The export of plants data was customized for this project with the help of Victoria Pennington (WYNDD).

The threats narrative in this project builds upon the information recorded and assembled by botanists at WYNDD over the years, first compiled for use in state species abstracts by Walter Fertig.

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INTRODUCTION

Energy developments are among the most widespread, recent, and dynamic activities in Wyoming, and there is little information on potential impacts to rare plants. This study provided a systematic evaluation of potential threats to Threatened, Endangered, and Bureau of Land Management (BLM) Sensitive plant species in Wyoming, hereafter referred to as Special Status Species (SSS). It also includes any other Wyoming plant species of concern (SOC) or potential concern (PSOC) that are present on BLM lands, referred to as "other rare species" for purposes of this report. A primary objective of this work was to determine the overlap between species' distributions and current/projected energy developments. It is patterned after a methodology employed by Wyoming Natural Diversity Database (WYNDD) zoologists referred to as an "Assessment of Wildlife Vulnerability to Energy Development" (AWVED; Keinath et al. 2008, Keinath et al. in progress). In this approach, Geographic Information System (GIS) tools are used to assess exposure to energy development across the predicted distribution of specific wildlife species. This project differs from the AWVED analysis in some basic ways. Most importantly, it addresses overlap of energy developments with documented species distribution (known distribution), rather than with predicted distribution. The use of known distribution represents a much more conservative approach that likely underrepresents the extent of exposure for species that have received relatively little survey effort. Other energy development threats (i.e., uranium and coal) were addressed based on overlays of these resources with known plant distributions.

For any given species, the risks posed by the threats are greatly conditioned by the **extent** of overlap between species' distribution and energy development. The risks are also conditioned by the **immediacy** of the threats, whether current or projected in the short-term or long-term. Finally, they are conditioned by the **severity** of threat, whether resulting in population extirpation, or else temporary or permanent decline. This report represents a first-time, spatially-explicit assessment of threat extent and immediacy. Results from the analyses are represented in quantitative terms for technical reference, and added to pre-existing information for streamlined narratives in state species abstracts.

The term "exposure" is used here to indicate overlap between documented plant distribution and proximal known or projected energy development structures, i.e., well pads and wind turbines, geospatially represented as exposure level intensities diminishing from the structures out to 1 km. Energy development may be associated with direct mortality and habitat loss or indirect decline and habitat alteration, including spread of invasive plants, soil disturbance, erosion, dust generation, and other implications. This is a generalization that warrants considerably more species information (e.g., plant life-histories, habitat requirements, and population dynamics), on-site data-collecting of habitat loss and alteration parameters, and robust analysis of those parameters as they potentially affect native plants with narrow geographic distribution. For example, an exemplary analysis was recently completed showing the relationship of invasive plant distribution and energy development features across southwestern Wyoming (Manier et al. 2014), demonstrating that some, but not all, of the seven invasive species studied are positively associated with development features.

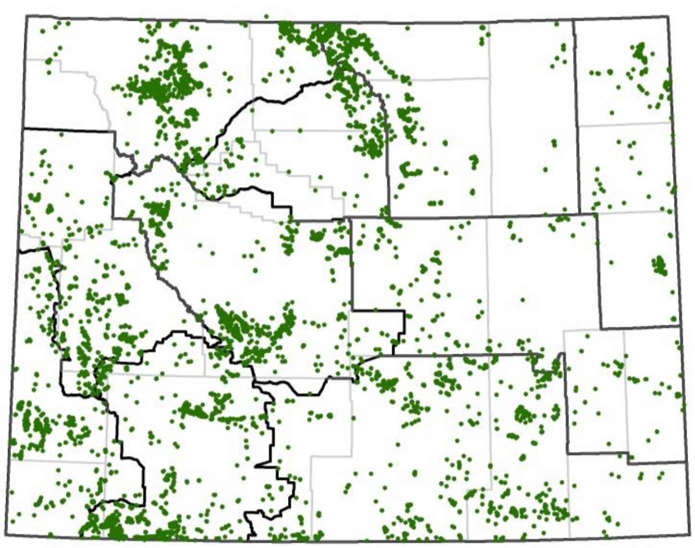
METHODS

Plant Data

All known records of 204 plant SSS, SOC and PSOC that are present on BLM lands were exported from the central database of WYNDD in May 2013[1]. Species known only from historical records (i.e., those that were documented before 1970 and with no subsequent data) were removed from this set because they generally have the most imprecise location information. Historical collections also represent species with some of the highest probabilities of habitat loss and local species' extirpation in intervening years, particularly those from arable settings on private land. Historical records represent less than 5% of all SOC, refining the list to a total of 194 species. Individual records were also excluded if they were not mapped to within 1-mile precision. All records mapped as polygons of occupied habitat were left as such. All records mapped as points were converted to a uniform polygonal buffer of 55 m radius. A 55 m buffer was used so that all shapes overlap with the center of at least one 30 m raster cell.

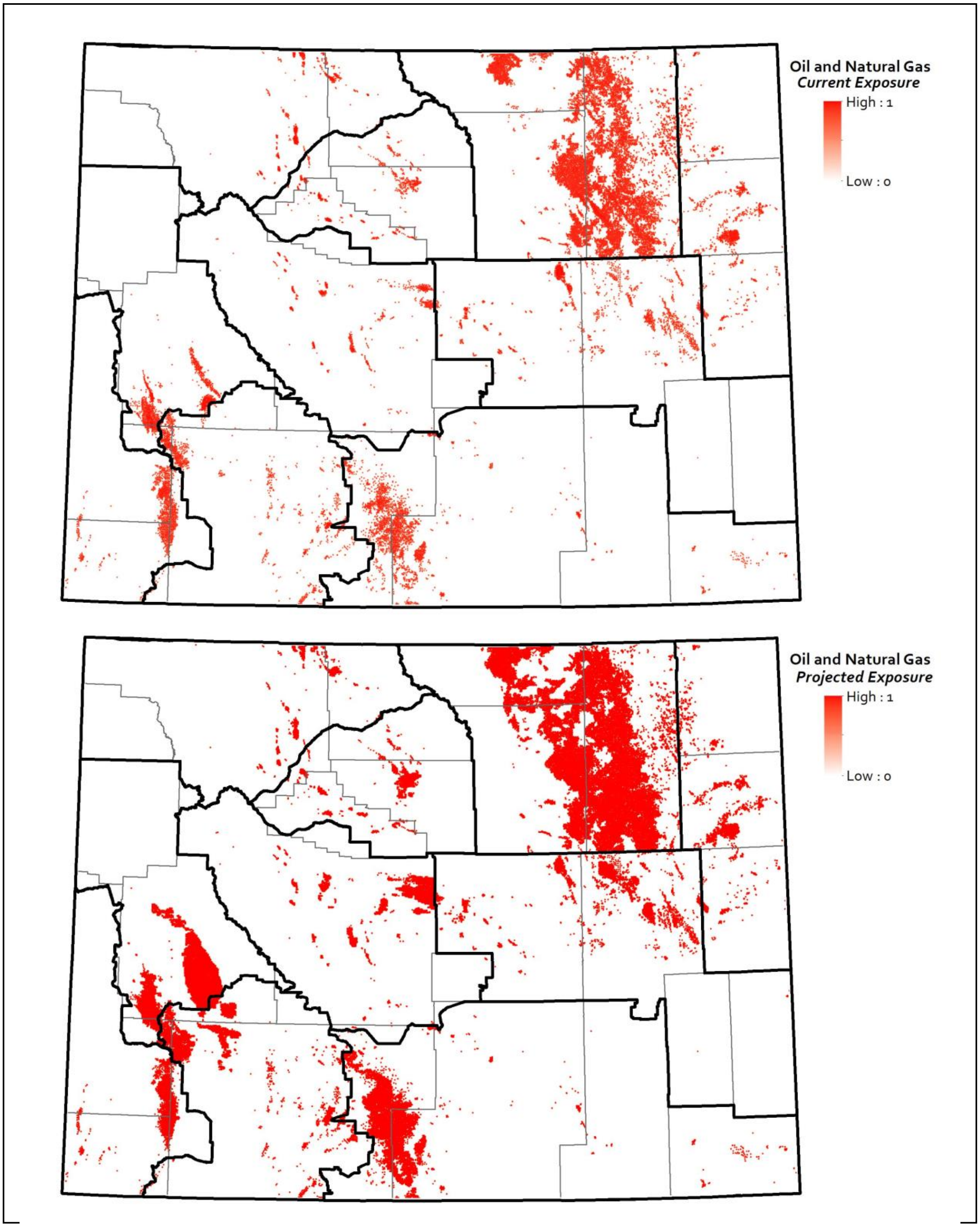
Records of SSS, SOC and PSOC are not randomly distributed, but reflect the biogeography of the plant species, pattern of public lands and other factors that condition the distribution of surveying and collecting efforts, availability of information, list criteria and development processes (Figure 1).

Figure 1. Distribution of SSS and other rare plant species in Wyoming

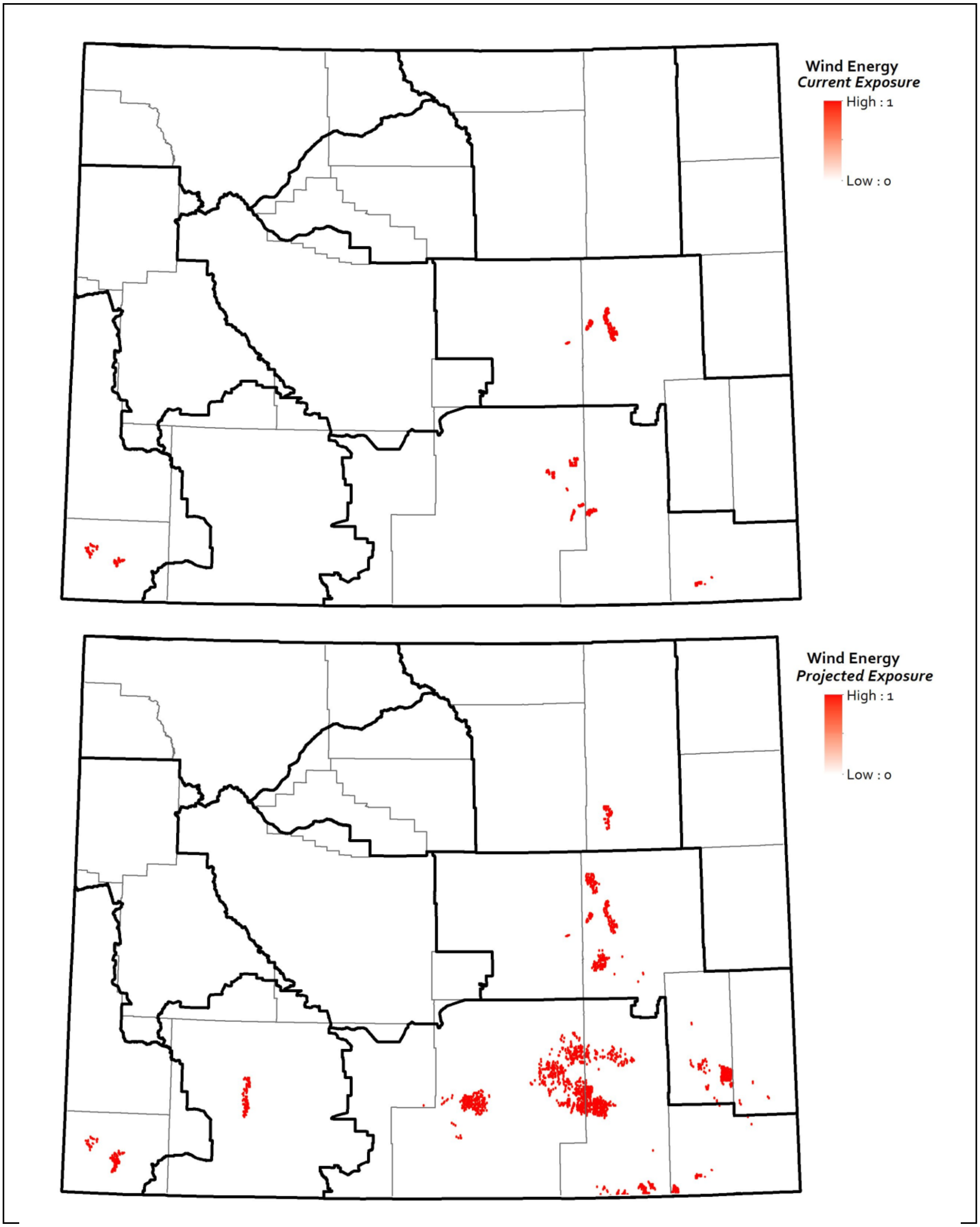


[1] This included all SSS plant species (USDI 2010) except for whitebark pine (*Pinus albicaulis*) and limber pine (*Pinus flexilis*), in addition to Colorado butterfly plant (*Gaura neomexicana* ssp. *coloradensis*) and narrowleaf moonwort (*Botrychium lineare*; the latter two are not present on BLM lands). The state species of concern and potential concern list draw from Heidel (2012), as reflecting documented or suspected presence on BLM-administered lands. The May 2013 data export was complete in representing the current distribution data with exception of *Cryptantha stricta*, most records of which were entered later in 2013.

Figures 2a and 2b. Current (top) and projected (bottom) exposure to oil & gas development in Wyoming



Figures 3a and 3b. Current (top) and projected (bottom) exposure to wind energy development in Wyoming



Energy Development Models

Energy Development Models were based on spatial models of current and proposed energy development exposure created for the AWVED (Keinath et al. 2008). The original maps represented: current oil & gas wells; projected oil & gas wells; current wind turbines; and projected wind turbines (Figures 2a and b, Figures 3a and b). The maps referred to as current oil & gas and wind development were based on actual well and turbine locations as of 2010 (reference year), which were obtained from the Wyoming Oil & Gas Conservation Commission (WOGCC 2010) and the U.S. Geological Survey (O'Donnell and Fancher 2010). Projected oil & gas maps estimated development through 2030 as reference year, based on forecasts drawn from 20-year Reasonable and Foreseeable Development Scenarios (RFDS) developed by the Department of the Interior for each BLM Field Office (e.g., Stilwell and Crocket 2004). For projected wind energy development, forecasts were drawn from projections by the U.S. Department of Energy (USDOE 2008). To assess exposure of plants to these energy developments, potential exposure surfaces were created by applying a logarithmic distance decay function to the current and projected well/turbine locations. This generated raster surfaces with values of 1 (maximum exposure) to 0 (no exposure) at distances of 0 to 1 km, respectively, from the wells/turbines. Note that this modeling approach used well/turbine locations as a surrogate for exposure from all the individual components that comprise energy infrastructure (e.g., roads, utility stations, power lines, pipe lines, etc.) and the ancillary impacts associated with those features (e.g., invasive weeds, and dust). This is a reasonable initial assumption when considering cumulative exposure over large spatial scales but does not afford the ability to assess fine-scale, site-specific impact.

The energy potential exposure surfaces were used to assess exposure to energy development for each of the target plant species. A Zonal Statistics calculation was done in ArcGIS 10.0, using the polygonal representations of the observation records for each species as the input zone, and each of the four energy exposure layers as the input rasters, resulting in a table that provided mean and standard deviation for modeled exposure of the target plant to each energy layer. The set of calculated exposure levels were one of two report products. Exposure levels were grouped into categories of high, moderate, low and very low based on thresholds at 45%, 15%, 5%, and 1% exposure, respectively (Appendix A). Those species with exposure levels in high, moderate or low exposure levels to current or potential threats are also described as such in narrative (Appendix B).

Other Energy Development Layers

A map of state uranium deposits (Gregory et al. 2010) was digitized to determine the presence/absence of their intersection with plant distribution records. The map of deposits does not represent all those that can be economically developed but is a first approximation.

A BLM coal lease GIS layer provided by the BLM State Office (2011) was used to determine the presence/absence of BLM coal leases as they overlap with known distribution of target plant species. It is important to note that the target plant species represent just those found on lands where BLM has surface management and does not represent all those where BLM holds mineral rights. Compared to spatial data for wind and for oil & gas, the uranium map represents both current and potential energy development while the coal lease map represents current energy development. Neither have buffers to represent zones of influence. There was no basis for placing them into high-, medium- or low- categories of current and potential threat levels.

Fire Effects Data

Information on each species' response to fire was sought in the Fire Effects Information System (FEIS; 2013), an on-line review prepared by Region 1 of the U.S. Service. It documents responses that may be either positive or negative, and may affect any aspect of life history or habitat suitability.

Expert Opinion

Species abstracts had been prepared at WYNDD starting in 1999 for many of the target species covered in this report. Species abstracts include narrative addressing whatever was known or could be inferred about threats to individual species, a synthesis of all species' status reports in Wyoming that addressed this topic as far back as the 1970s. Almost all plant status reports produced in Wyoming were by Robert Dorn or by WYNDD under different affiliations. Many of the species were reported as having threats that were unknown or considered to be negligible. Other species had no threats information on file. An evaluation of threats has always been part of the WYNDD and NatureServe process for assigning Global- and State-ranks. More recently, a refined framework of scoring threat vectors and cumulative impact was developed and incorporated into ranking processes. The nature of this ranking work as it involves potential threats requires synthesizing all primary and secondary information sources including field observations.

The pre-existing threats information drew from Wyoming status reports including WYNDD studies and from information gathered during state and global ranking updates as a compilation of botanical expert opinion. All expert opinion information on threats currently stored as narrative was weighed and expanded or edited as appropriate. Field observations of immediate and potential threats as addressed in more recent survey reports were searched and incorporated. The following guidelines were prepared for standardizing information on threats in the general narrative. The resulting narrative for the target species is presented in Appendix B.

Consolidation of Results in Species Abstract Narratives

The GIS output was translated into text and incorporated, along with secondary source information, into state species abstracts. In the absence of any written guidelines, the following conventions were developed to standardize and expand existing threats narratives and to prepare new narratives.

Scope/Severity/Immediacy

The scope and immediacy of each oil & gas or wind energy potential threat was addressed by placing each target species into a high-, medium- or low- exposure category, under current and potential threats, as assessed by the GIS overlap analysis.

Sequence

The most widespread and certain of threats was mentioned first in the narrative for each species. The least important or uncertain threats are mentioned last. The information derived from the GIS analysis replaced the existing narrative if they both addressed the same potential energy development threat. Energy developments that were once described as potential threats that did not overlap in this GIS analysis were deleted.

Consistency

Use of the same wording helps draw parallels. For example, the words "Potentially threatened by" replaced many similar terms such as "may be affected/impacted/influenced by" in cases where potential threats were identified by observation or well-informed deduction. Likewise, "logging" replaced "timber harvest/timber sales/thinning/clearcutting". Similarly, "road work" was described as a threat regardless of whether the road is a 2-track or an interstate highway, a new road or a potential road, and whether the species is threatened by the construction activity or by the maintenance activity. Other conventions and terminology used in the narrative are defined as follows:

"***Threats associated with***" – Threats that were identified in the GIS exposure analysis.

"***Immediate threats are inferred to be low***" – This wording was used to flag the inferred lack of threats for those species that are in alpine, rugged/rocky or other remote habitats. The possibility of threats in such settings were not dismissed but put into a framework for further consideration.

"***Vulnerable to***" – Referring to threats from natural disturbances and natural phenomena, a subtle way of distinguishing between threats that may be controllable from those that are not.

"***Unknown***" – Referring to the unknowable threats (species known only from historical specimens whose survival is unknown) and other species with extremely scant information.

"***In the past***" – Differentiating threats that have caused one or more population extirpations in the past but there is question whether such threats are ongoing.

"***Persists under***" – Described natural or man-made disturbance in which a species is known to persist. Some target species tolerate human disturbances and may warrant reconsideration if their persistence is, in fact, dependent on human disturbance.

"***Potentially dependent on stable***…" – Referring to species that might require relict habitat, i.e., habitat which cannot be restored or mitigated.

Source of Information

Narrative drew mainly from Wyoming information sources, rather than from sources outside of Wyoming, unless directly relevant. Exceptions were made in mentioning any commercial or hobby collecting of plants anywhere in the range because information about plant collecting in Wyoming is scant or unreliable, and collecting elsewhere is a gauge of potential threat in Wyoming. If threats were identified and discussed in a status report, or drawn from this project, citations were included for these information sources.

Detail

As a GIS study, the information to address each direct and indirect disturbance agent of energy development as potential threats is not represented. Disturbance agents might include exploration, road construction, facilities construction, pipeline and transmission line installation, and other associated practices; or the different expressions that these practices might take such as habitat loss, habitat degradation, fragmentation, weed invasion, erosion, dust and others. Weed invasion, in particular, is addressed by Manier et al. (2014), suggesting that some invasive species are positively associated with energy developments while other invasive species had little or no clear correlation. Such weed invasion threats can exist apart from energy development and are named separately in cases where there was pre-existing field evidence. In such cases, weed invasion was treated generally to include all competitive exotic species and not just noxious ones, without naming the individual species. "Exotic aquatic species" referred to either non-native plants or animals whose invasion changes habitat suitability.

Distinctions were not made between indirect and direct effects of threats, and whether they affect the species or its habitat. If these are discussed in greater detail in some report, the report citation was added. In select cases, distinction is made between livestock grazing and livestock trampling.

All mentions of "habitat decline," "habitat degradation" or "loss of water quality" were removed from pre-existing threats narrative because all species are vulnerable to changes in habitat quality and suitability. The phrases are ambiguous. Instead, the original vectors of natural change and the agents of human impact were identified in the narrative if there was supporting information.

RESULTS

The majority of all 194 plant species (148 species; 76.3%) have negligible or no exposure (measured exposure values <1%) to either oil & gas development or wind development at current or projected levels (Table 1, Appendix A). More SSS and other rare species are affected by current oil & gas wells than by current or projected wind turbines (Table 1).

Table 1. Tallies of BLM SSS and other rare plant species with energy development exposures

Energy development and reference year	No. of SSS with greater than 1% exposure	No. of all other SOC and PSOC with greater than 1% exposure	Maximum exposure levels (among all species)
Current oil & gas wells (2010)	8	22	33.5%
Projected oil & gas wells (2030)	11	30	89.7%
Current wind turbines (2010)	0	0	0%
Projected wind turbines (2030)	1	6	6.0%

For visual reference and representation purposes, exposure values are reported in Appendix A, highlighting the individual species that had high (over 45%), moderate (15+ - 45%), low (5+ - 15%), or very low (1+-5%) exposure values in a color code. Values below 1% are not highlighted. The categories were natural breaks in the exposure continuum and it is up to BLM to determine what exposure levels are basis for management concern in the mandate to maintain species' viability. Fifteen species have high exposure to oil & gas development at current or projected levels, there are five SSS among the 15, and the 15 are distributed in nine of ten BLM Field Offices in Wyoming (Table 2). Only one species, Laramie false sagebrush (*Sphaeromeria simplex*), has greater than 5% exposure to wind development at projected levels, i.e., a low exposure level.

Table 2. SSS and other plant species with moderate/ high oil & gas energy exposure levels

Scientific name	**Common name**	**BLM status**	**BLM Field Office(s)**[2]	**Oil & Gas exposure level – current**	**Oil/Gas exposure level - projected**
Achnatherum swallenii	Swallen's mountain-ricegrass		Kemmerer, Pinedale, Rock Springs	Moderate	High
Artemisia porteri	Porter's sagebrush	Sensitive	Buffalo, Casper, Lander	-	Moderate
Astragalus drabelliformis	Big Piney milkvetch		Pinedale	Moderate	High
Astragalus racemosus var. *treleasei*	Trelease's racemose milkvetch	Sensitive	Kemmerer, Pinedale	Moderate	Moderate
Cirsium aridum	Cedar Rim thistle	Sensitive	Lander, Pinedale?	Moderate	Moderate
Eriogonum corymbosum var. *corymbosum*	Crisp-leaf buckwheat		Rock Springs	Moderate	Moderate
Eriogonum divaricatum	Divergent buckwheat		Kemmerer, Pinedale, Rock Springs	Moderate	Moderate
Kobresia simpliciuscula	Simple kobresia		Pinedale	-	Moderate
Lathyrus lanszwertii var. *lanszwertii*	Nevada sweetpea		Kemmerer, Worland?	-	Moderate
Nothocalais troximoides	False agoseris		Cody	Moderate	Moderate
Phacelia salina	Nelson's phacelia		Pinedale, Rawlins, Rock Springs	-	High
Phlox opalensis	Opal phlox		Kemmerer, Pinedale, Rock Springs	-	Moderate
Phlox pungens	Beaver Rim phlox	Sensitive	Kemmerer, Lander, Pinedale, Rock Springs	-	Moderate
Populus deltoides var. *wislizeni*	Fremont cottonwood		Rawlins	Moderate	Moderate
Spiranthes diluvialis	Ute ladies'-tresses	Threatened	Casper, Rawlins	-	Moderate

As for other energy developments, there was only one SSS species and seven other species that had overlap with coal mining (Table 3). There were ten SSS species and 24 other species that had overlap with uranium mining (Table 3). The quantitative difference between the two may be a function of the difference in mapping potential resources (uranium) vs. existing leases (coal).

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[2] A question mark is inserted after Field Office name if the species is only known from record(s) that have unresolved questions as to their taxonomic validity.

Table 3. SSS and other plant species with distribution overlapping coal and uranium resources[3]

Scientific name	**Common name**	**BLM status**	**BLM Field Office**	**Coal**	**Uranium**
Achnatherum nevadense	Nevada needlegrass		Lander, Rawlins, Rock Springs		X
Antennaria arcuata	Meadow pussytoes	Sensitive	Lander, Pinedale, Rock Springs		X
Artemisia biennis var. *diffusa*	Mystery wormwood		Rock Springs?	X	X
Artemisia porteri	Porter's sagebrush	Sensitive	Buffalo, Casper, Lander		X
Asclepias subverticillata	Bedstraw milkweed		Rawlins?	X	
Astragalus barrii	Barr's milkvetch		Buffalo, Casper, Newcastle	X	X
Astragalus bisulcatus var. *haydenianus*	Hayden's milkvetch		Lander, Kemmerer, Rawlins, Rock Springs		X
Astragalus diversifolius	Meadow milkvetch	Sensitive	Lander, Rawlins		X
Astragalus nelsonianus	Nelson's milkvetch		Casper, Lander, Rawlins, Rock Springs		X
Boechera crandallii	Crandall's rockcress		Rawlins, Rock Springs	X	X
Boechera pendulina var. *russeola*	Daggett rockcress		Casper, Lander, Rawlins, Rock Springs		X
Cirsium aridum	Cedar Rim thistle	Sensitive	Lander, Pinedale?		X
Cryptantha stricta	Erect cryptantha		Lander		X
Cryptantha subcapitata	Owl Creek miner's candle	Sensitive	Lander		X
Descurainia pinnata var. *paysonii*	Payson's tansymustard		Rawlins, Rock Springs	X	X
Elymus simplex var. *luxurians*	Long-awned alkali wild-rye	Sensitive	Rock Springs		X
Eriastrum wilcoxii	Wilcox eriastrum		Lander, Rawlins, Rock Spring		X
Eriogonum divaricatum	Divergent buckwheat		Kemmerer, Pinedale, Rock Springs		X
Eriogonum exilifolium	Slender-leaved wild buckwheat		Rawlins		X
Eriogonum hookeri	Hooker buckwheat		Rawlins?, Rock Springs	X	
Ipomopsis crebrifolia	Compact ipomopsis		Kemmerer, Pinedale, Rock Springs		X
Lesquerella macrocarpa	Large-fruited bladderpod	Sensitive	Kemmerer, Pinedale, Rock Springs		X
Loeflingia squarrosa	Spreading loeflingia		New Castle?, Rock Springs?		X
Machaeranthera coloradoensis	Colorado spiny aster		Rawlins		X
Oxytropis nana	Wyoming locoweed		Casper, Lander, Newcastle, Rawlins		X
Pectis angustifolia var. *angustifolia*	Lemon scent		Casper?	X	
Penstemon gibbensii	Gibbens' beardtongue	Sensitive	Rawlins		X
Penstemon paysoniorum	Payson Beardtongue		Casper, Kemmerer, Lander, Pinedale, Rock Springs		X
Phacelia demissa	Intermountain phacelia		Rock Springs		X
Phacelia salina	Nelson phacelia		Pinedale, Rawlins, Rock Springs		X
Phacelia tetramera	Tiny phacelia		Rawlins, Rock Springs		X
Phlox opalensis	Opal phlox		Kemmerer, Pinedale, Rock Springs		X
Physaria saximontana var. saximontana	Rocky Mountain twinpod	Sensitive	Lander, Worland		X
Polygala verticillata	Whorled milkwort		Newcastle		X
Rorippa calycina	Persistent sepal yellowcress	Sensitive	Cody, Lander, Rawlins, Worland	X	X
Sphaeromeria simplex	Laramie false sagebrush	Sensitive	Rawlins		X
Spiranthes diluvialis	Ute ladies' tresses	Threatened	Casper		X

[3] A question mark is inserted after Field Office name if the species is only known from record(s) that have unresolved questions as to their exact location or taxonomic validity.

DISCUSSION

Two of the main goals of the BLM Wyoming sensitive species policy are to maintain vulnerable species and habitat components in functional BLM ecosystems, and to prevent a need for species listing under the Endangered Species Act. This study provides preliminary threats evaluation for SSS and other vulnerable species, a springboard for expanding the current state of knowledge in order to maintain them. Most SSS are state endemics or concentrated in Wyoming, so if they are potentially threatened by Wyoming energy developments, then overall species' viability is potentially threatened.

Some oil & gas fields were developed in the 1990's more recently than the plant records, but before there was a formal BLM SSS list. It is possible that a review of overlaps between plant distribution and wells could be pursued by BLM to identify, on-the-ground, whether or not past practices caused any loss or decline to the habitat and the population. This hard data would be valuable to better understand the levels and nature of threats by oil & gas development to SSS species, and in identifying agency priorities for possibly more detailed threats assessment. Such a review might focus on at least those two SSS species with moderate exposure to oil & gas development under current levels (*Astragalus racemosus* var. *treleasei* and *Cirsium aridum*, as identified in Table 2). However, the Sublette County distribution of the latter has been questioned (Heidel 2013), and all voucher specimens warrant review. So the immediate SSS priority for BLM consideration, as identified by these methods, rests with on-the-ground review of *Astragalus racemosus* var. *treleasei* populations that overlap with oil fields.

To prevent a need for listing, three additional SSS species that have moderate or high exposure levels to projected energy developments (Table 2) might be worth closer on-the-ground BLM evaluations of energy development impacts (*Artemisia porteri*, *Phlox pungens* and *Spiranthes diluvialis*). Less than half of the fifteen species with moderate or high exposure to current/future oil & gas development have BLM status. Some of them are peripheral in Wyoming, such as Nevada sweetpea (*Lathyrus lanszwertii* var. *lanszwertii*), for which threats do not have the same level of importance in species' viability as threats to species that are endemic to Wyoming such as Big Piney milkvetch (*Astragalus drabelliformis*). The latter species might warrant updated status review because its entire distribution is confined to Wyoming, primarily on BLM lands, and though found at many sites in the 1990s (Kass 1995), many are now in oil fields.

The overlap between energy developments and known distribution rather than potential distribution models is geographically conservative, even though buffers and exposure distance functions were used in the analysis. By contrast, vertebrate potential distribution models were used for analyzing energy exposure in Wyoming (Keinath et al. 2008). A few of the plant species in Table 2 are represented by less than five known records in the state. These species include Crisp-leaf buckwheat (*Eriogonum corymbosum* var. *corymbosum*), Nevada sweetpea, False agoseris (*Nothocalais troximoides*), and Fremont cottonwood (*Populus deltoides* var. *wislizeni*) and are peripheral in Wyoming compared to their continental distribution. They have not been singled out for systematic surveys and may be either intrinsically rare in the state or under-documented rather than jeopardized in Wyoming by oil & gas developments.

There are disclaimers to add to this initial analysis. A full literature review of threats to each species has not been conducted as part of this study, although we incorporated what was already compiled in existing sources such as species conservation assessments produced for the Rocky Mountain Region of the U.S. Forest Service. Species-specific information on threats is generally scarce, and incorporating information on threats to other members of the same genus is often tenuous. Furthermore, the difference between spatial analysis and field analysis can be big. The reader is referred to in-depth Colorado studies that quantify the responses of two Threatened plant species to specific energy developments and the severity of these threats or lack thereof (e.g., Kurzel et al. 2010, Clark 2010). The Colorado studies tended to document lower on-site impacts to populations than predicted by spatial analysis. It is also worth mentioning that many of the species are microhabitat specialists and their habitat may not support developments or be affected by them.

The distribution data used in this analysis is the most robust data available. The degree to which species have been mapped across the landscape and the mapping conventions may affect outcome. Species such as Big Piney milkvetch (*Astragalus drabelliformis*) have been mapped mainly as point data with limited information on their landscape extent. So even though it is known from many locations, their representation as points may have bearing on outcome. As a state endemic, it already has been the focus of systematic surveys (Kass 1995).

Among potential threats, there have been no rigorous assessments of SSS responses to widespread management practices such as livestock grazing. The only preliminary evaluations draw from years of field observations tempered by an understanding of species' palatability and observations of livestock use in occupied habitat, as done in a pilot U.S. Forest Service study (Fertig 1995). There have been no rigorous assessments of SSS responses to widespread natural disturbances such as fire apart from literature reviews (Hessl and Spackman 1995, FEIS 2013).

Species' responses to climate changes were not addressed in this study. Only one of the SSS in this report has been treated in such analysis, Laramie false sagebrush (*Sphaeromeria simplex*) (Treher et al. 2012). Such work is beyond the scope of this study.

Database tools have been developed by NatureServe for use by WYNDD to produce much more elaborate, hierarchical estimates of species conservation ranks, and for evaluating threats as a component of species' ranks. The latter include itemization of threats, categorizing their scope, immediacy and severity, and then automatically rolling up their cumulative impacts. The database tools are relatively new but could be valuable in the ranking process. However, like all such tools, their output is only as good as the data that is provided to them. Although this study provides some indications of plant threats due to energy development, and thus will help refine conservation ranks somewhat, the information presented here is a distant substitute for more robust data on species- and location-specific threats collected in the field. These tools and this evaluation highlight the importance of the environmental review process for BLM SSS plant species.

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