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UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF IDAHO

WESTERN WATERSHEDS PROJECT, WILDEARTH GUARDIANS, CENTER FOR BIOLOGICAL DIVERSITY, and PRAIRIE HILLS AUDUBON SOCIETY, *Plaintiffs*, v. DAVID BERNHARDT, Secretary of Interior; JOSEPH R. BALASH,* Assistant Secretary of Interior; BUREAU OF LAND MANAGEMENT; and U.S. FOREST SERVICE, *Defendants*.	Case No. 1:16-cv-00083-BLW **DECLARATION OF AMY HAAK, Ph.D**

* *Official Defendant automatically substituted per Fed. R. Civ. P. 25(d)*

I, Amy Haak, hereby declare as follows:

1. My name is Amy Haak and I reside in Boise, Idaho. This declaration is based on my personal knowledge and if called as a witness I would and could truthfully testify to the matters stated here.

Summary of Work Performed

2. I was asked to conduct a range-wide habitat analysis within Greater Sage-grouse priority areas. The purpose of my analysis was to evaluate how well priority areas for sage-grouse conservation capture historical levels of habitat diversity and the efficacy of the 2015 and 2019 Resource Management Plan Amendments in the long-term conservation of that diversity.

Qualifications and Experience

3. I have over 30 years of professional experience in the application of geospatial technologies to environmental characterization and natural resource modeling. I hold a Bachelors of Arts degree in Geography from Dartmouth College (1980), a Master of Science degree in Geography (specializing in Land Management) from the University of Idaho (1984), and a PhD in Geography with a minor in Conservation Biology from the University of Idaho (2004).

4. Presently, I am the Executive Director of Conservation Geography, a non-profit corporation that provides analytical support to non-profit conservation organizations. In my capacity with Conservation Geography, I have provided expert assistance and testimony in several sage-grouse litigation matters before the U.S. District Court for the District of Idaho, and I am familiar with sage-grouse science and literature.

5. I also previously served as the assistant director of Trout Unlimited's National Science Program for over a decade. Working in this capacity I developed analytical methodologies to support native trout conservation based on the founding principles of conservation biology: Representation, Resilience, and Redundancy – the 3-Rs. I gave numerous

presentations on this methodology, provided training to inter-agency work groups, and published peer-reviewed articles on the approach (Haak and Williams 2013; Haak and Williams 2012; Haak et al. 2010).

Scientific Foundation of Analysis

6. The analysis I present in this declaration is founded in the principles of conservation biology as they pertain to the preservation of biodiversity. Specifically, I draw on portfolio theory and the 3-R framework as described below. For more detailed information on the methods and data sets used in the analysis described herewith, see my white paper entitled *Conservation Portfolio of Sage-grouse Core Habitat* (attached as Exhibit 1). This paper has been reviewed by biologists knowledgeable of sage-grouse science.

Portfolio Theory and the 3-R Framework

7. One of the basic tenets of conservation biology is that biological diversity provides stability (Primack 2002). Biologically rich systems can more easily withstand disturbance and swings in environmental conditions that would destabilize communities dominated by few species or species dominated by only a few small populations. The ability of diverse natural systems to maintain their function and productivity in the face of rapid environmental change has been termed the ‘portfolio effect’, a concept analogous to the desire among financial managers to maintain a diverse economic portfolio as a hedge on uncertain futures (Figge 2004). A diversified portfolio seeks to optimize the mix of assets associated with different risk classes in order to provide a hedge against catastrophic conditions. There is no exact quantitative measure for a balanced portfolio but rather it is evaluated along a continuum from historical levels of diversity to current or future conditions – the more elements of historical diversity that are still present today, the more balanced the portfolio and the more stable the

community. To characterize the diversity within a conservation portfolio, I use the 3-R framework.

8. The 3-R framework provides a structure to describe levels of diversity for a conservation element such as a species or its habitat (Shaffer and Stein 2000, Haak and Williams 2012). The elements of the 3-R framework are described as follows:

- Representation – retention of each unique element of diversity (e.g. genetics, life history traits, geographic diversity) across the environmental gradients of a species' range in order to conserve the adaptive capacity of a species or its habitat.
- Resilience – the ability of a species or its habitat to recover from disturbances. This typically equates to the size of populations or extent of the habitat with large unfragmented populations and habitats being the most resilient.
- Redundancy – multiple geographically dispersed populations and habitats so that one can be lost without jeopardizing the whole. This is the safety net that provides a hedge against the loss of any single population or habitat.

9. The 3-R framework has been recognized and adopted by the U.S. Fish and Wildlife Service in developing recovery plans for threatened and endangered species (Carroll et al. 2006), and in assessing greater sage-grouse conservation measures, as discussed below.

<u>The 3-R Framework and Greater Sage-grouse</u>

10. Landscape-scale species such as the Greater Sage-grouse exhibit behavioral strategies and adaptations that historically enabled individuals to disperse and exploit a variety of site-specific habitats across disparate geographies. Populations occurring in marginal and unique habitats outside of the core areas, often at the periphery of a species' range, are important to

long-term persistence since they contain a disproportionate percentage of the species' genetic variation and evolutionary potential for adaptation (Araujo and Williams 2001, Hampe and Petit 2005, Haak et al. 2010).

11. In 2013, the U.S. Fish and Wildlife Service released a peer-reviewed report of its Conservation Objectives Team (COT) that describes range-wide conservation objectives for greater sage-grouse, which itself employs the 3-R approach. (U.S. Fish and Wildlife Service 2013).

12. The COT Report identified 301 Priority Areas for Conservation (PACs) that it termed "key habitats essential for sage-grouse conservation." As I explain further below, the PACs were the basis for priority habitat designations made by BLM and U.S. Forest Service in their 2015 Sage-Grouse Plans.

13. In identifying the PACs for special land management protection, Section 4 of the COT Report describes their Conservation Framework stating: "We used three parameters – population and habitat **representation, redundancy, and resilience** … as guiding concepts in developing our conservation goal, priority areas for conservation, conservation objectives, and measures.' (emphasis added). This is the same 3-Rs approach I describe and utilize here.

14. Of particular relevance to my analysis is the COT Report's application of the 3-Rs to habitat (as well as populations) and the emphasis placed on "*conserving well distributed sage-grouse populations across* ***geographic and ecological gradients***' (*Id.,* p. 12) (emphasis added). This underscores the importance of preserving habitat diversity across the full extent of the species' range.

15. I analyzed the 301 PACs from the COT Report using Geographic Information System (GIS) software (ArcMap 10.5) and published spatial data sets encompassing the entire

historical sage-grouse range. Results are stratified by the Sage-grouse Management Zones (MZ) as defined by the Western Association of Fish and Wildlife Agencies (WAFWA).

16. My analysis found that the PACs encompass 43% of occupied sage-grouse habitat within the United States. As shown in Figure 1 below, the 301 areas include 96% of the high and moderate-high density breeding sites as defined by Doherty et al. (2011). In delineating the PACs, the FWS associated them with 32 populations and metapopulations represented by different colors in Figure 1.

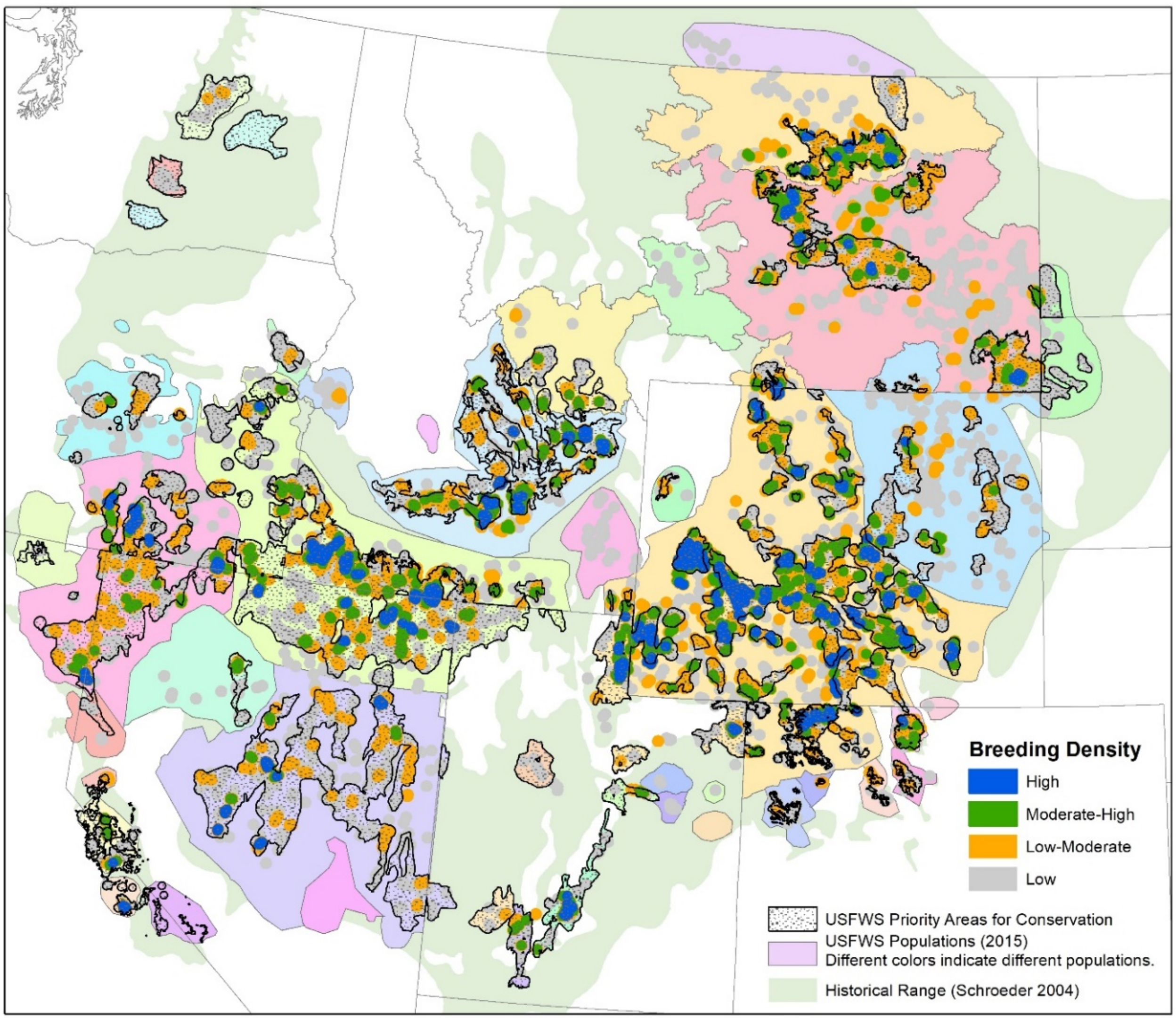

Figure 1. USFWS Priority Areas for Conservation and breeding concentration areas.

Representation

17. The objective of the representation analysis is to determine how well the PACs encompass the array of habitats historically available to sage-grouse. Recent studies have found that the population response to breeding habitat varies across the occupied range, indicating that habitat selection is more complex than simply the presence of sagebrush (Doherty et al. 2016). Loss of this diversity may constrain seasonal habitat selection and reduce the capacity of sage-grouse to adapt to changing environmental conditions.

18. Habitat is characterized at multiple scales using published data layers that integrate biotic and abiotic factors across environmental gradients without anthropogenic influences, thus allowing for historical comparisons. The use of multiple scales allows for the identification of entire ecosystems not represented in the PACs, as well as site-specific habitats that may be falling through the cracks. Specifically, the four habitat-based data layers used in this analysis are: Sage-grouse Management Zones, Level III Ecoregions, Level IV Ecoregions, and elevation.

19. Each of these four habitat delineations were summarized by MZ for the historical range and priority areas. These summations were used to identify habitats that are not captured in the PACs, as well as those that were rare historically (i.e. comprise less than 5% of the historical range) or are at risk of being lost to the range-wide portfolio (i.e. occur at less than 10% of the historical extent). The cumulative area of rare and vulnerable habitats was calculated for each priority area as a percentage of the total PAC area to highlight those PACs encompassing the greatest concentration of under-represented habitats.

20. Table 1 below summarizes the results of the representation analysis by management zone and Figure 2 shows the spatial distribution of the results.

Representation				
MZ	Number of PACs			
	High	Moderate	Non-contributing	Total
I	13	8	4	25
II	23	11	72	106
III	33	3	38	74
IV	11	9	35	55
V	6	4	9	19
VI	4	0	0	4
VII	18	0	0	18
Total	**108**	**35**	**158**	**301**

Table 1. Summary by Management Zone of the Representation Analysis.

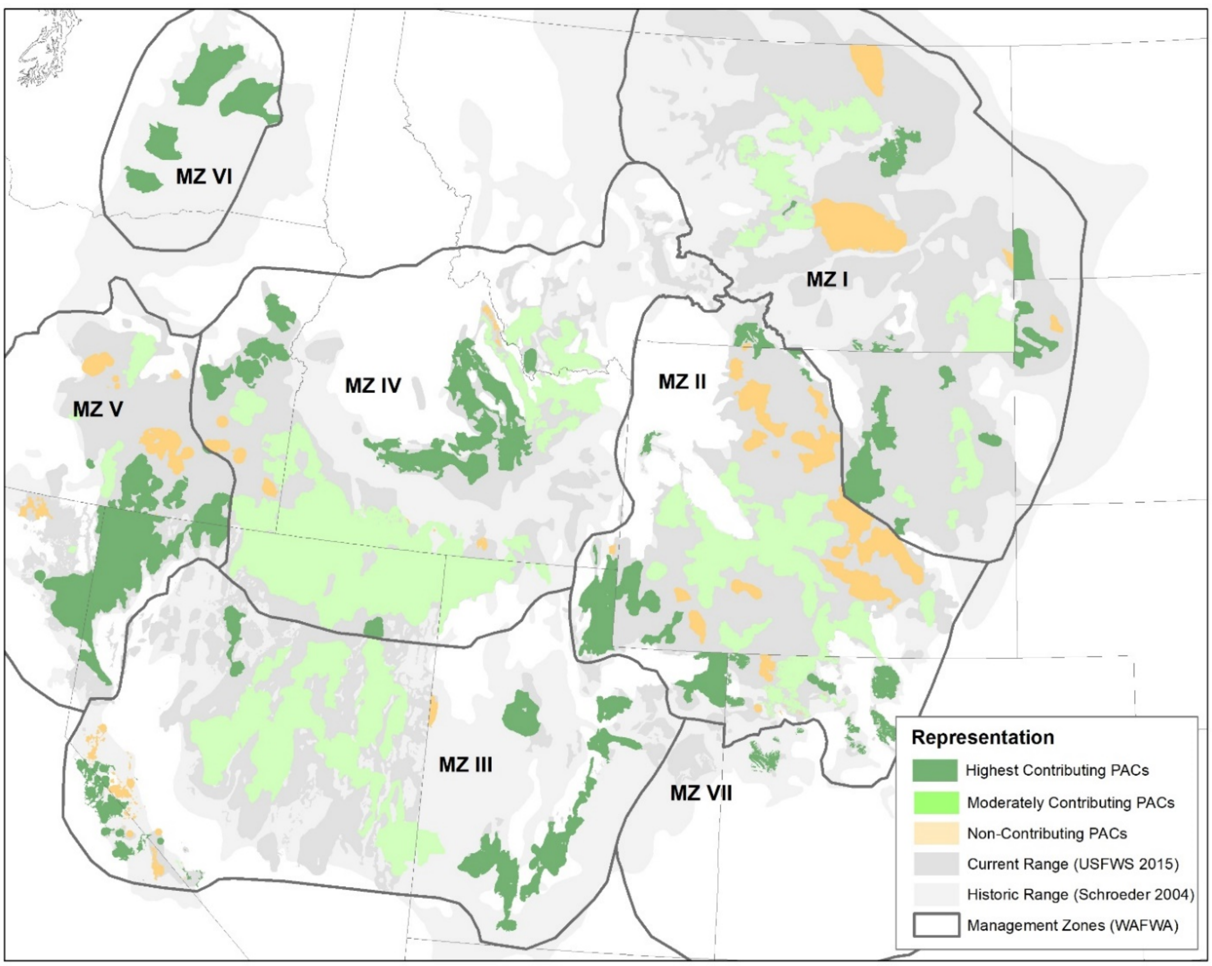

Figure 2. Results of the Representation Analysis.

21. The PACs shown in dark green in Figure 2, above, encompass the highest concentration of under-represented habitats. These areas are either wholly contained within one of the target elements, or include multiple overlapping targets such that the cumulative area exceeds the total area of the PAC. The PACs shown in light green in Figure 2 also contain target habitats but at a lower concentration. The PACs in beige are comprised entirely of habitats that are well-represented within the priority area network.

22. From a range-wide perspective, many of the highest priority areas are found around the margins of the currently occupied habitat where individuals disperse to the edges of their suitable habitat, exploiting environments that differ from the centrally located core areas. This is particularly evident in zones VI (Columbia Basin) and VII (Colorado Plateau). These zones are located at the northwestern and southeastern extents of the historical range, respectively, and all of the PACs within the two zones contain rare and/or at-risk habitats. In MZ III (Southern Great Basin), the PACs in Utah and California contain a high concentration of under-represented and rare habitats compared to the centralized core areas in Nevada. A visual comparison between the current and historical ranges shown in Figure 2 shows the disproportionate loss of habitat in Utah compared to Nevada.

23. In addition to under-representation of the range margins, my analysis also found that the PACs are associated primarily with higher elevation uplands when compared to the historical distribution. Historically 52% of the range was below 1,500 meters but only 27% of the priority areas are found at this elevation.

<u>Resilience</u>

24. My resilience analysis evaluates the PACs' inherent resistance and resilience to wildfire, a growing threat to sage-grouse habitat. Historically, fire regimes in the sagebrush

landscapes ranged from 20-25 years in wetter regions where more fuel was available to 60-100 years in arid sage-steppe habitats of southern Idaho. In particularly dry areas such as Nevada, fire did not have a strong influence on the landscape (Welch 2005).

25. Changes across the sagebrush landscape beginning in the 1900's, particularly the rapid spread of cheatgrass, altered the natural resistance and resilience to wildfire of sage-grouse habitat. The warm and dry soil regimes of southern Idaho and northern Nevada now facilitate the spread of cheatgrass resulting in an increase in the frequency and size of wildfires. This situation is further exacerbated by rising temperatures and persistent droughts associated with climate change as well as anthropogenic impacts that stress and alter natural processes (Chambers et al. 2017).

26. Table 2 provides decadal summaries from 1984-2017 of the number of fires, maximum size, and total area burned across the historical range of sage-grouse. While the near doubling of the number of fires is alarming, the fivefold increase in the number of large fires (over 100,000 acres) from the decade 1984-1993 to 2004-2013 is particularly troubling for the future of sage-grouse in these now fire-prone ecosystems.

Years	Number of Fires	Largest Fire (acres)	Total Area Burned (acres)	Number of Fires Over 100,000 acres
1984-1993	793	228,161	6,059,419	6
1994-2003	1,430	236,451	13,313,852	15
2004-2013	1,324	567,409	16,571,252	33
2014-2017	1,292	646,452	7,580,338	15

Table 2. Fire statistics for the historical range of sage-grouse. Summaries based on fire perimeter data developed by the Geospatial Multi-Agency Coordination Group (GeoMAC).

27. My analysis of wildfire resilience is based on five variables: resistance to cheatgrass (Chambers et al. 2017), topographic diversity, 1984-2017 area burned, patch size, and connectivity (Crist et al. 2015). The first three factors address a site's inherent resistance to

wildfire, while patch size and connectivity are important for post-fire recovery. Large, well-connected, and diverse habitats with native plant communities will fare the best during and after a wildfire.

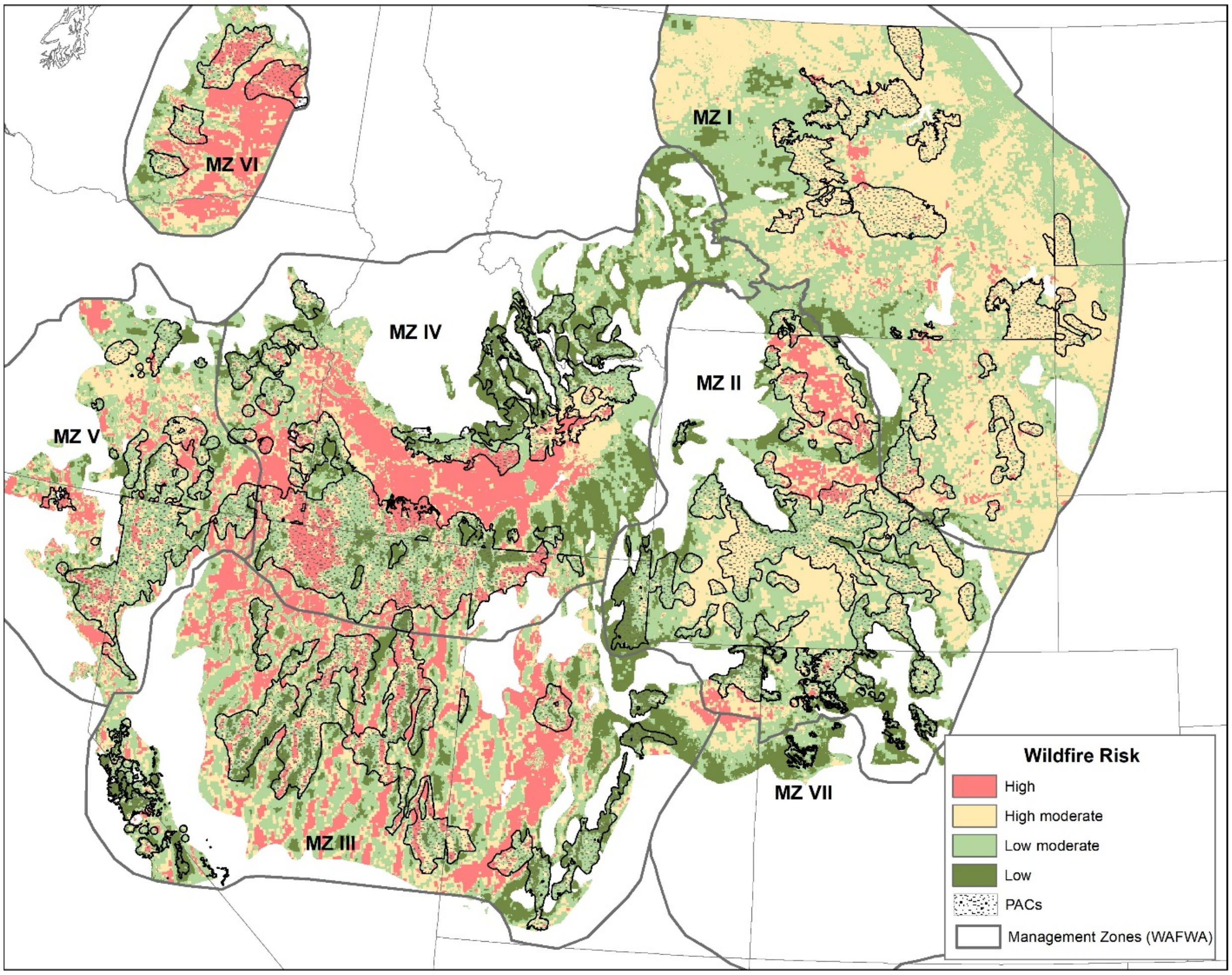

Figure 3. Results of wildfire risk analysis based on resistance to cheatgrass, topographic diversity, and recent fire history.

28. Figure 3 above shows the combined results of the three landscape characteristics contributing to wildfire risk (i.e. cheatgrass resistance, recent fire history, and topography). The juxtaposition of these three factors can help to mitigate some of the inherent risk. Areas with low cheatgrass resistance such as the Great Basin in MZs III, IV, and V may experience a more diverse mosaic of burn intensities if there is a high degree of topographic diversity than a similar site within a uniform landscape. Similarly, areas such as the Great Plains region in MZ I that are

moderately resistant to cheatgrass but have little topographic diversity have the potential for wildfires to spread rapidly under hot and dry conditions.

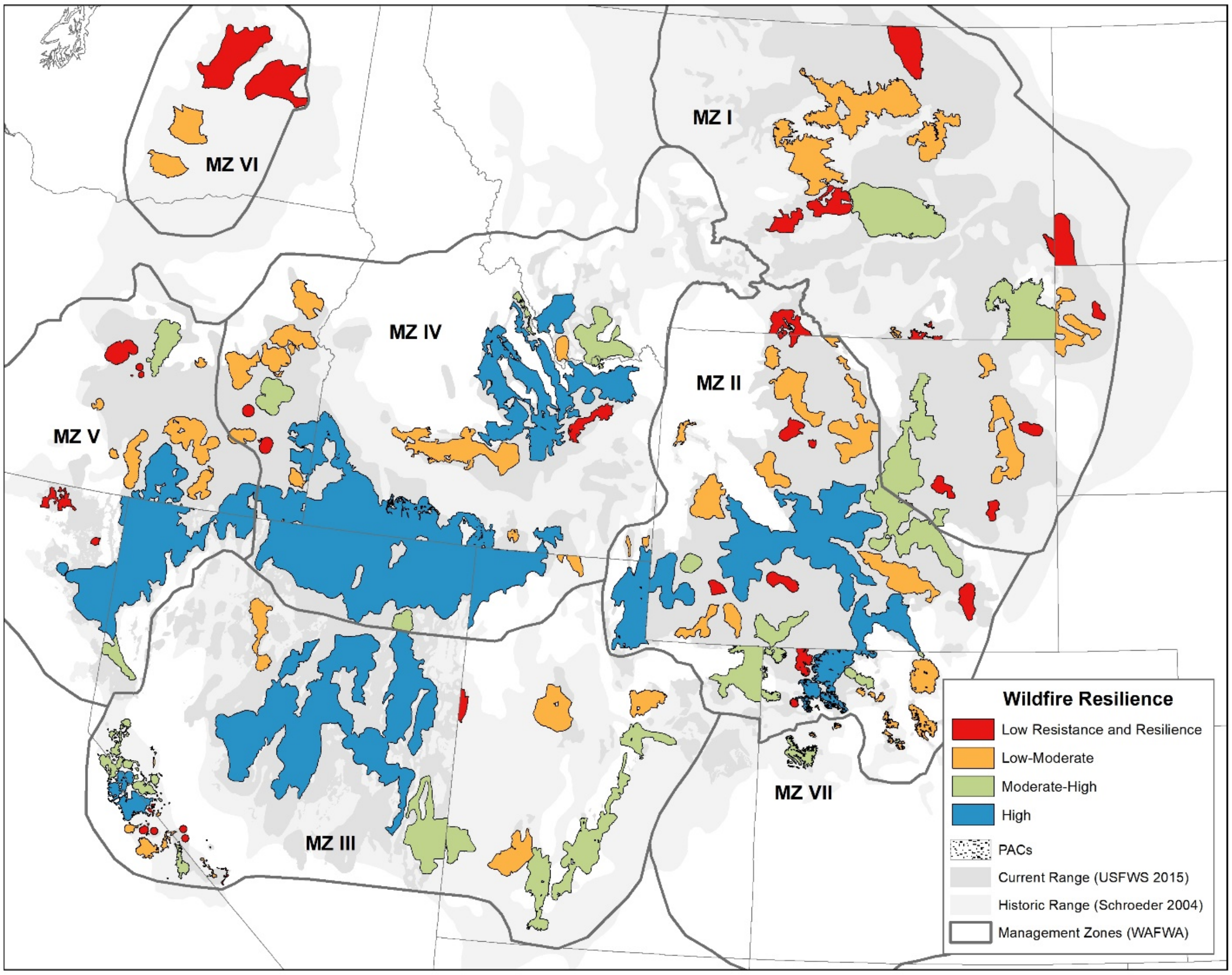

Figure 4. Results of resilience analysis. PACs shown in red have low resistance to wildfire and natural recovery is limited due to small patch size and isolation. PACs in blue have higher resistance and better potential for natural recovery.

29. Figure 4 above shows the results of the resilience analysis. The PACs shown in blue have the highest resilience while those in red have the least. Many of the large PACs classified as resilient contain areas within them that are highly vulnerable to wildfire due to the presence of cheatgrass. However, these PACs also encompass diverse terrain and habitats that can mitigate wildfire effects at the landscape scale and facilitate natural recovery from unburned patches within the wildfire perimeter.

30. Pathways within the large PACs facilitate the movement of wildlife in response to disturbance events. Therefore, when considered as a single contiguous unit, they are classified as resilient. In contrast, the small isolated patches in fire-prone landscapes are more likely to burn in their entirety and will be more difficult to restore due to a lack of seed sources. Access to suitable habitat as wildfire refugia is also more difficult for resident populations in these highly fragmented landscapes.

Redundancy

31. The redundancy analysis is assessed for the Management Zones with the goal of having multiple priority areas within each zone that are capable of supporting a population of sage-grouse. This insures that the unique characteristics associated with each zone are not lost to a single disturbance. Many of the PACs are very small and may not support all of the seasonal habitat needs for a population, functioning instead as stepping stones between larger patches. Therefore, a patch size criterium of 600 km^2 was applied based on the annual home range requirements for a resident individual (Connelly et al. 2011).

32. In addition to size, it is also important for a PAC to support a breeding concentration area that can sustain a population should adjacent patches and populations be lost. For this I relied on the breeding density as characterized by Doherty et al. (2011) and shown previously in Figure 1. Those PACs that did not contain any breeding concentration areas above the lowest density were classified as not contributing to redundancy.

33. Table 3 and Figure 5 below show the results of the redundancy analysis. Of the 301 PACs, only 62 (20%) meet both the size and breeding density criteria for redundancy and only 10 of these also meet the criteria for wildfire resilience. Range-wide, over 56% of the

priority areas are both too small and have too low of a breeding density to contribute to redundancy.

Redundancy						
MZ	Number of PACs					
	Redundant and Resilient	Contributes to Redundancy	Less than 600 km2	Low Breeding Density	LT 600 km2 & Low Breeding Density	Total
I	0	12	6	0	7	25
II	3	18	31	0	54	106
III	2	8	5	1	58	74
IV	4	7	11	2	31	55
V	1	5	4	2	7	19
VI	0	1	0	3	0	4
VII	0	1	4	0	13	18
Total	**10**	**52**	**61**	**8**	**170**	**301**

Table 3. Summary of Redundancy analysis by Management Zone.

34. The lack of resilient PACs in MZ I is offset by 12 well-distributed PACs that satisfy both the size and breeding density criteria for redundancy, thus providing an important safety net should some of the PACs be rendered unsuitable due to wildfire. In contrast, MZs VI and VII do not contain any resilient patches, and each have only one PAC that meets both the size and breeding density criteria for redundancy. Seventeen of the 18 PACs in MZ VII do not meet the size criteria and 13 fail to meet both the size and breeding density criteria. With so many small PACs vulnerable to loss from a disturbance event, the long-term representation of this entire MZ is dependent on a single PAC with no safety net.

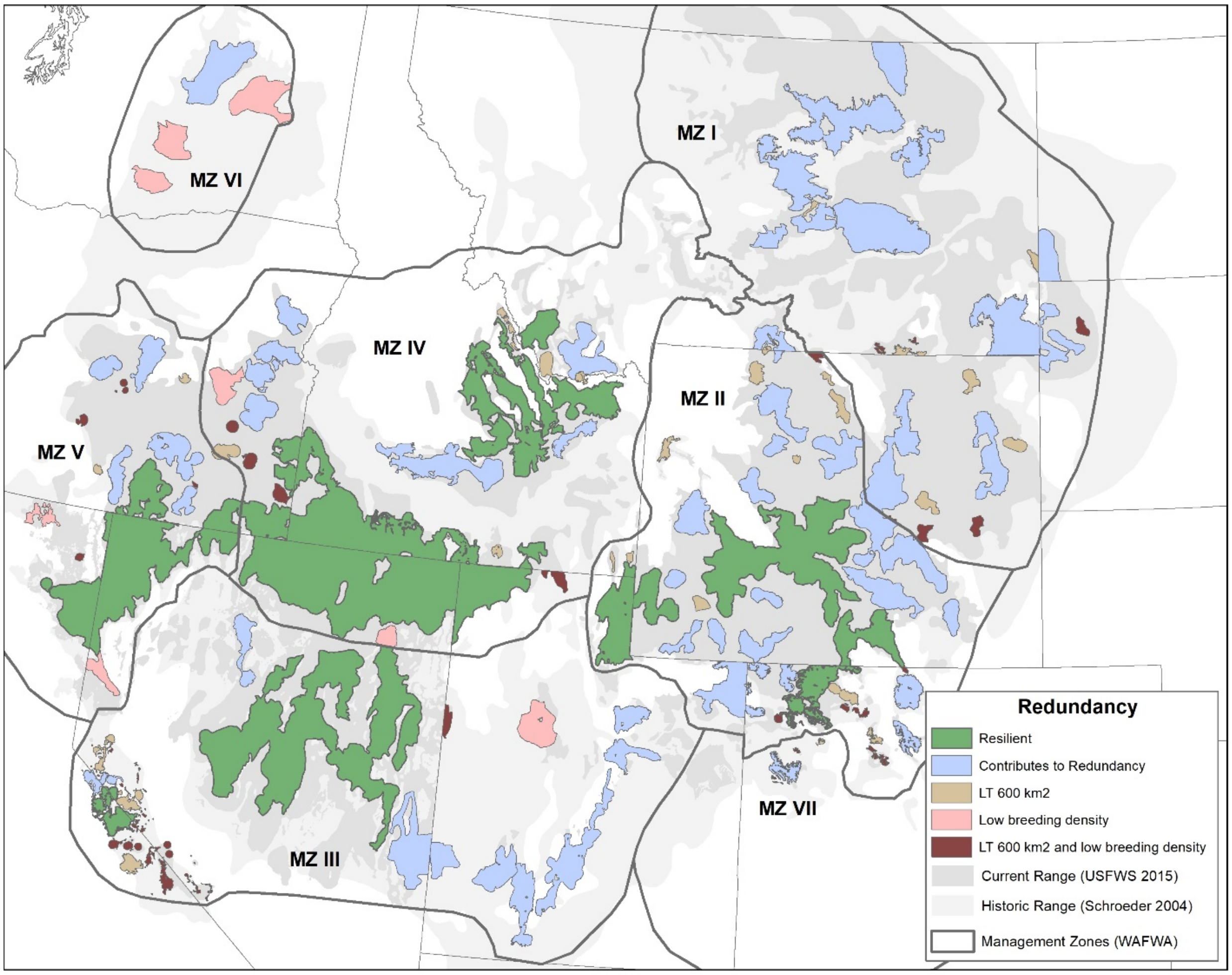

Figure 5. Results of redundancy analysis. Dark green PACs were classified as the most resilient in the previous analysis and satisfy the redundancy criteria for size and breeding density. PACs shown in blue are less resistant and resilient to wildfire but meet the minimum requirements for Redundancy of being at least 600 km2 in size and containing at least one breeding density concentration area of 75% or better.

35. Management Zones II, III, IV, and V each support one or more large resilient PAC as well as at least five PACs that meet the redundancy criteria and are fairly well distributed within each management zone. The exception is in the eastern portion of MZ III where the isolated Sheeprocks PAC represents the last vestige of sage-grouse habitat within a large expanse of central Utah, and does not satisfy the redundancy criteria due to a low breeding density. This PAC is vulnerable to local extirpation, and with no other core habitat patches in the region the unique attributes of this portion of the historical range will be lost.

36. The separation of MZ VI from the other management zones makes redundancy particularly important to the persistence of the Columbia Basin sage-grouse populations in the range-wide portfolio. However, while all four of the priority areas satisfy the size criteria for redundancy, only one satisfies the criteria for breeding density. A similar situation exists in MZ VII. Although there are more priority areas delineated in this region, they are small and only one satisfies the redundancy criteria leaving the Colorado Plateau highly vulnerable to regional extirpation.

Summary of Conservation Portfolio Analysis

37. The results of this analysis demonstrate that the portfolio for sage-grouse priority habitat is lacking across all three metrics (i.e. representation, resilience, and redundancy) when compared to historical conditions. However, these losses have not occurred uniformly across the species' range. All of the metrics evaluated for representation showed an increased concentration of the most common habitat types within the priority areas while the habitats that were more limited historically have decreased representation. This pattern of loss is particularly evident at the lower elevations and around the range margins.

38. Resilience has also decreased within the range-wide portfolio when compared to historical conditions. Some of the largest remaining habitat patches occur in southern Idaho, northern Nevada and southeastern Oregon where the warm dry climate is conducive to the spread of cheatgrass, leading to more frequent and higher intensity wildfires. In spite of their vulnerability to wildfire, these PACs were classified as resilient due to their large extent and diverse terrain. Future fragmentation of these PACs that results in multiple small homogeneous patches would lead to a loss of regional resilience. Where small fire prone patches exist, connectivity to other suitable habitats is essential.

39. In the absence of resiliency, redundancy is important to the preservation of a diverse portfolio. Many of the high priority PACs for representation are scattered in small patches along the range margins. Over 75% of the priority areas are less than 600 km^2. While many of them occur in clusters, should an area become isolated due to a disturbance event or the loss of connectivity between patches, it is unlikely that the small isolated patches will provide for long-term population persistence, resulting in further reductions to the portfolio diversity.

40. The diversity that has been captured in the range-wide portfolio is highly vulnerable. Of the 108 PACs contributing the most to range-wide habitat diversity, only 36 (33%) were classified with moderate to high resilience and just 27 (25%) meet the criteria for redundancy. Overall, 56 of these 108 PACs, covering over 1.5 million hectares, have low resilience to wildfire and fail to meet the size and breeding density criteria for redundancy.

Effect of 2015 Plan Amendments on Sage-Grouse Conservation Portfolio

41. The 2015 BLM and USFS Sage-Grouse Management Plans used the PAC delineations in development of special management designations for sage-grouse conservation. Figure 6 below shows the 2015 Plans' habitat designations for sage-grouse priority habitats. Note that Management Zone VI (Columbia Basin) and the Bi-State sage-grouse population in Management Zone III (California/Nevada border) were not included in the 2015 Plans, so no special designations exist for these PACs under the 2015 Plans.

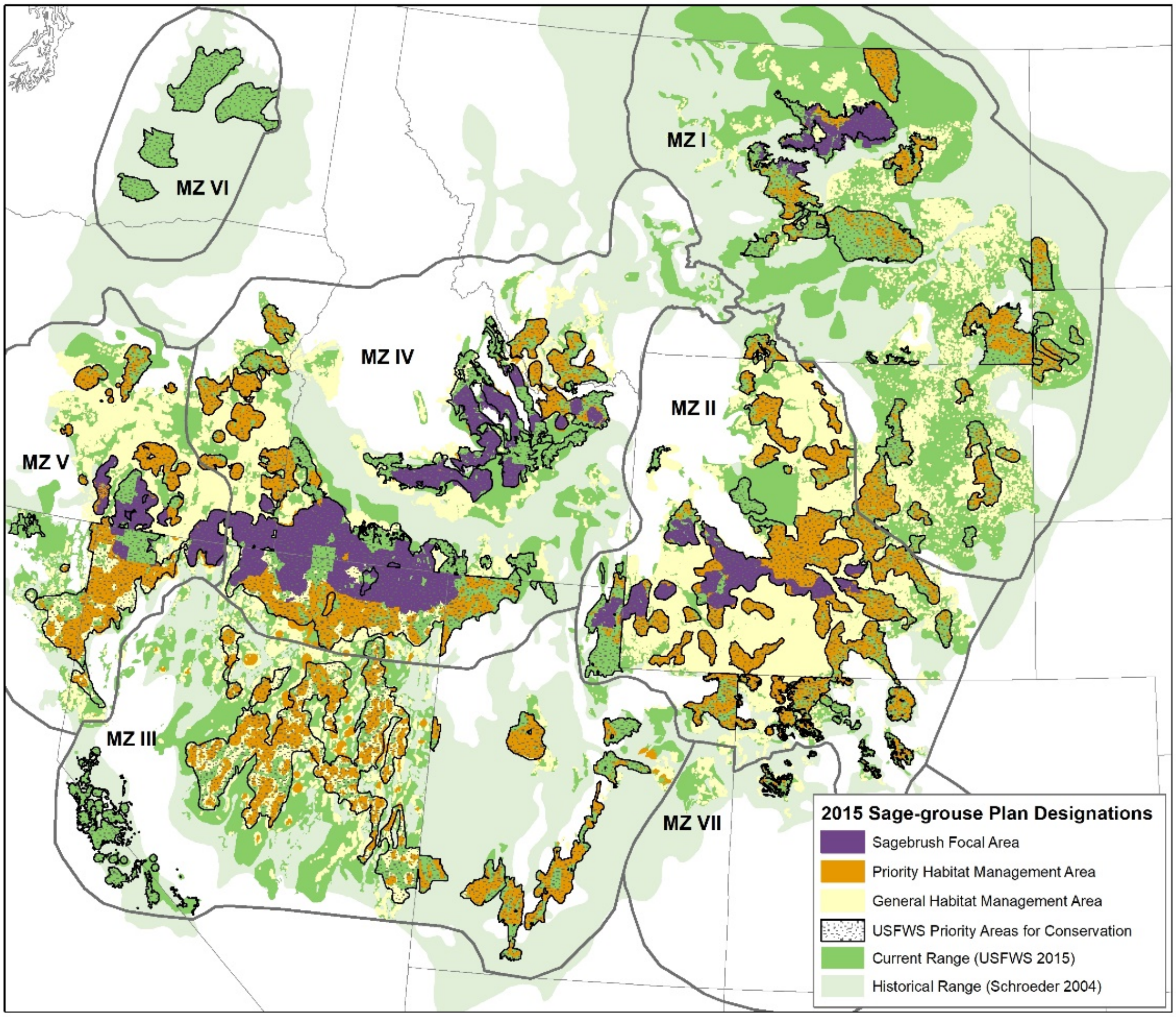

Figure 6. Sage-grouse management designations from 2015 Resource Management Plan Amendments

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42. As Figure 6 illustrates, within the priority habitat designations of the 2015 Plans, the Sagebrush Focal Areas (SFAs) provide the greatest protection for sage-grouse but cover less than 15% of the habitat within the PACs. Though not as protective as the SFAs, the Priority Habitat Management Areas (PHMAs) provide some protection for an additional 28% of the priority areas. This leaves over one-half of the habitat within the PACs with little or no special management guidelines for sage-grouse (i.e. undesignated or General Habitat Management Area – GHMA).

43. While not all of the land within the PACs is under the jurisdiction of the BLM or USFS, the lands that are within their management should be afforded the highest level of protection given the importance of the PACs to sage-grouse conservation and their vulnerability to wildfire, which is exacerbated by surface-disturbing activities that contribute to the spread of cheatgrass and the loss of native vegetation. Table 4 below provides a summary of the 2015 Plans' designations for the PACs within each management zone.

2015 Plan Designations in PACs					
MZ	Hectares				
	Total Area	SFA	PHMA	GHMA	Other
I	4,736,711	348,853	993,074	437	34,555
II	6,936,285	841,853	2,735,255	2,079	9,077
III	6,078,620	0	2,012,815	1,064,667	507,093
IV	9,142,483	2,774,520	1,897,641	266,142	1,132,668
V	3,269,665	636,261	1,211,478	275,748	158,248
VI	1,092,810	0	0	0	0
VII	94,387	0	23,669	0	0
Total	**31,350,961**	**4,601,487**	**8,873,932**	**1,609,073**	**1,841,641**

Table 4. Area summaries for 2015 plan designations within PACs.

44. Sage-grouse habitat outside of the PACs is either undesignated or classified as GHMA, which provides limited protection. While these areas are critically important to sage-grouse, there is a tendency in the delineation of priority areas to focus on centrally located habitats and population strongholds, such that unique habitats and low abundance populations outside of the core areas often fall through the cracks (Smith et al. 2016).

45. Recent studies have emphasized the importance of the landscape outside of the core areas as stopover habitat for long-distance migrants and corridors to seasonal habitats (Newton et al. 2017; Crist et al.2015) as well as pathways for genetic connectivity and dispersal from population centers to low population areas around the range margins (Cross et al. 2018;

Heinrichs et al 2018; Row et al. 2018). These surrounding habitats are also important for the preservation of conservation options as environmental conditions change (Burkhalter et al. 2018).

46. My analysis thus concurs with other recent studies (e.g., Crist et al. 2015; Smith et al. 2016) in finding that the 2015 Sage-Grouse Plans did not encompass all sage-grouse habitats in their priority habitat designations for special management attention and protection. Moreover, the SFA and PHMA designations, which have the highest level of protections, failed to include vital habitats outside the "core areas" designated around breeding/nesting sites, such as winter concentration areas or connectivity habitat. As a result, the 2015 Plans did not go far enough in identifying and protecting sage-grouse habitats necessary to ensure conservation of the species, under the 3-Rs analysis.

2015 – 2019 Landscape Changes

47. Since adoption of the 2015 Sage-Grouse Plans in September of that year there have continued to be adverse changes to the sage-grouse landscape. Of particular concern are wildfire and energy development. I have calculated the respective and cumulative acreages of lands impacted within the sage-grouse range from fourth quarter 2015 through first quarter 2019 using GIS software and data sets developed by agencies within the Department of the Interior. I downloaded the wildfire perimeters for 2016-2018 from the U.S. Geological Survey's GeoMAC (Geospatial Multi-Agency Coordination) website and the spatial and tabular data on oil and gas leases was downloaded for each quarterly lease sale from the oil and gas leasing section of the BLM's Energy and Minerals website. The GIS data on lease sales included an attribute indicating whether or not a parcel had been sold.

Wildfire

48. Figure 7 below shows the burn perimeters for wildfires that have occurred in the sage-grouse landscape since adoption of the 2015 Sage-Grouse Plan. Range-wide, 1.8 million hectares (about 4,550,000 acres) have burned in the currently occupied habitat over the past three fire seasons, including over 1.1 million hectares (over 2,800,000 acres) in the PACs. Over 65% of the area burned within PACs occurred in MZ IV (Snake River Plain) and another 12% was in MZ VI (Columbia Basin).

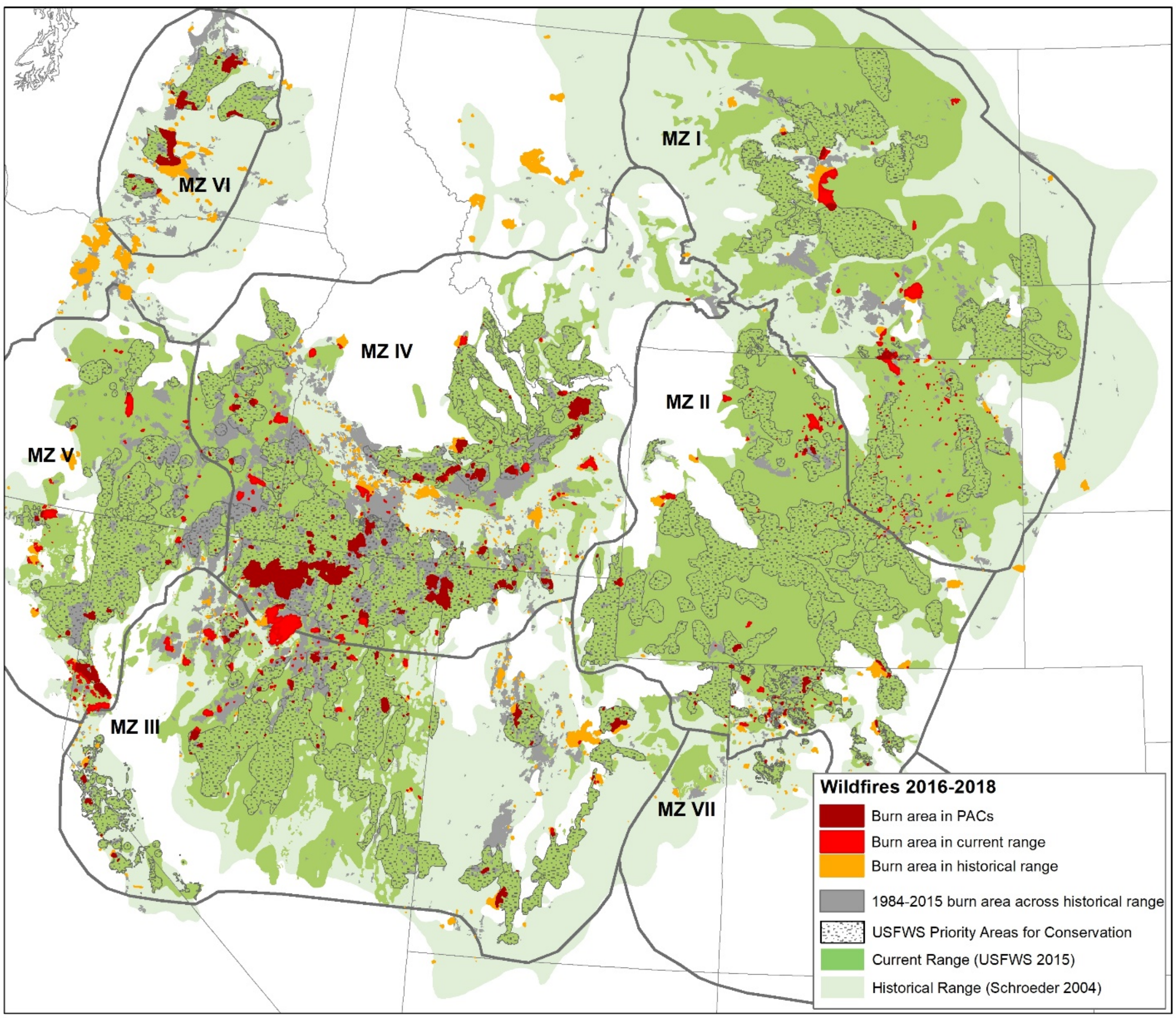

Figure 7. Wildfires in sage-grouse habitat from 2016-2018.

49. In reviewing the entire burn history since 1984, it is evident that the cheatgrass-prone regions of southern Idaho, northern Nevada, and southeastern Oregon have experienced the most extensive wildfires, a pattern which is intensifying with climate change. This is particularly concerning given the importance of this region as a sage-grouse stronghold.

50. The numerous wildfires in this region underscores that large PACs may lose their resilience and function as effective habitat for sage-grouse, undermining the ability of PACs to function as cohesive unit and maintain internal pathways such that populations displaced by wildfire can move to another area of suitable habitat within the PAC. If the PAC becomes fragmented and these important pathways are severed, the area-wide resilience will be lost. In its place will be diminished island habitats that may not sustain sage-grouse populations at the same level and will be difficult to restore.

51. With the increasing frequency and intensity of wildfires throughout this region, it is essential that connectivity within large PACs and between small ones be maintained. Activities that contribute to the spread of cheatgrass should be limited.

Energy Development

52. In addition to wildfires, the development of oil and natural gas resources is also adversely impacting sage-grouse habitat, particularly in Wyoming. The cool moister climate of Wyoming has thus far insulated the region from the cheatgrass invasion seen in Idaho and Nevada. As a result, the area has not experienced the same frequency and intensity of wildfires as occurs in the warmer and drier climates. However, as shown in Figure 8 below, oil and gas wells are found across much of the sage-grouse habitat in the eastern portion of its range.

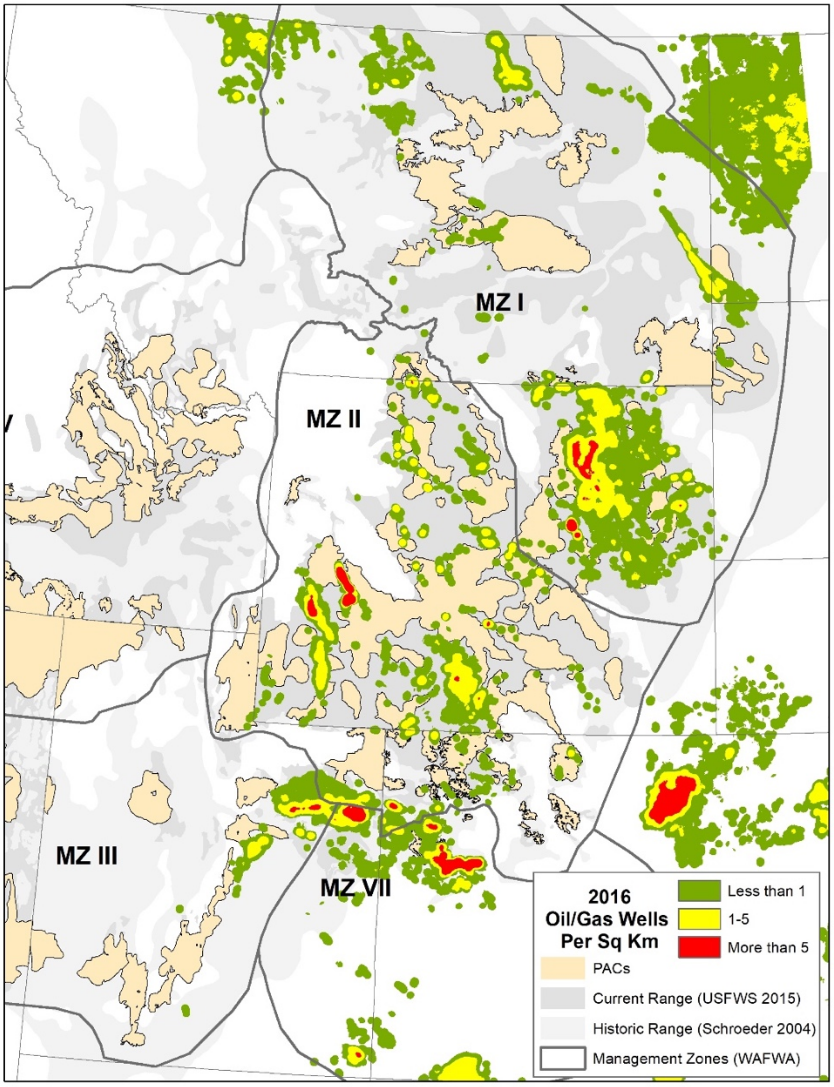

Figure 8. Density of oil and gas wells in sage-grouse habitat as of 2016. Raster data developed by the BLM as part of their sage-grouse threats analysis.

53. Since adoption of the 2015 plans, the BLM has continued to offer quarterly lease sales in sage-grouse habitat, including priority areas. Figure 9 below shows the leases offered and sold within the current range for sage-grouse from the 4th quarter of 2015 up through the 1st quarter of 2019. Although 1,126 leases were offered in Nevada during this timeframe, only 99 were sold – less than 10%. A much different situation exists in Wyoming where 5,772 leases were offered in sage-grouse habitat and 64% (3,694) of them were sold.

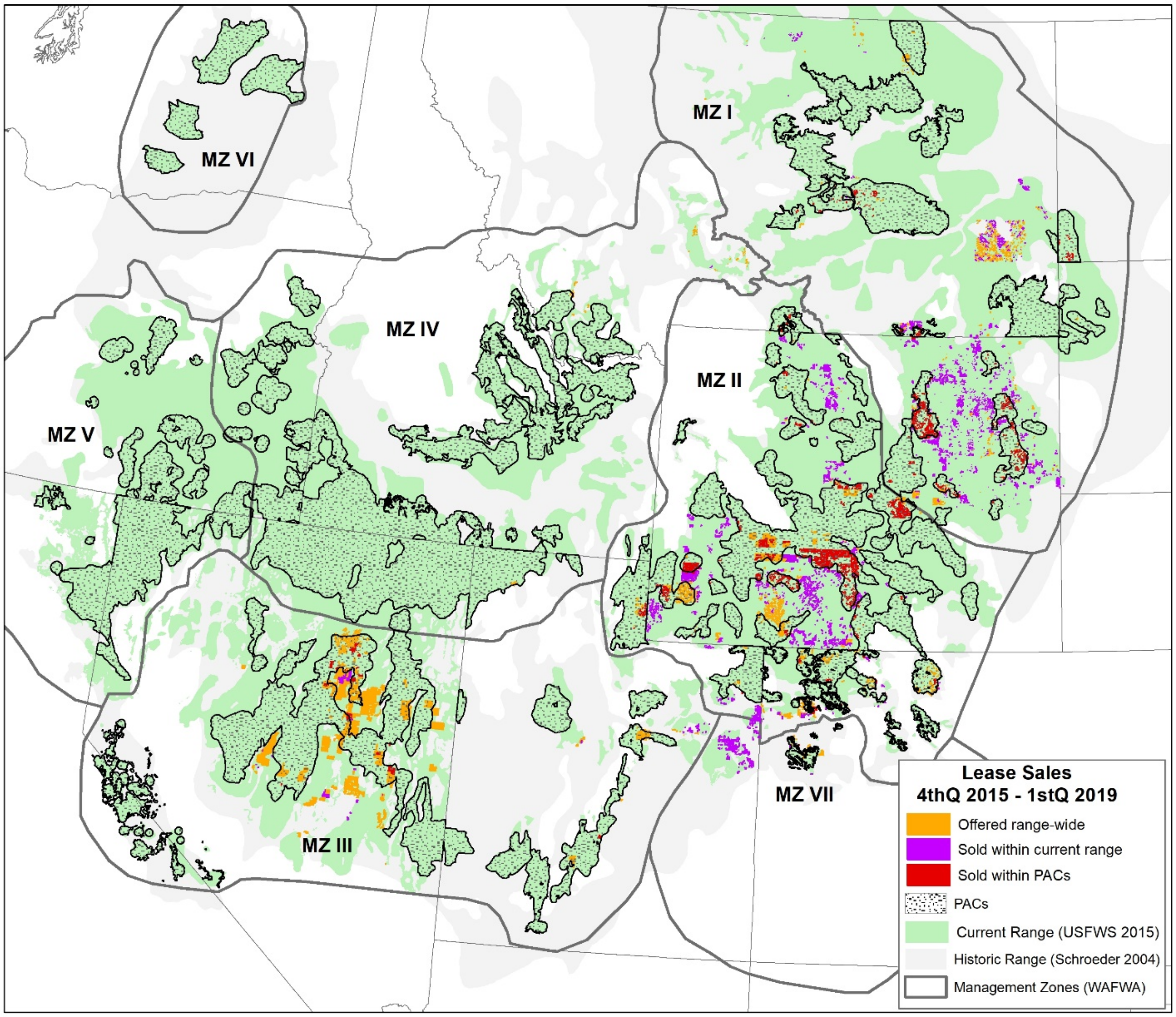

Figure 9. Oil and gas lease offerings from the 4th quarter of 2015 through the 1st quarter of 2019.

54. The industrialization of sage-grouse habitat with developed infrastructure and increased human activity has been found to alter sage-grouse behavior, eventually resulting in the abandonment of breeding sites as yearlings disperse to other areas (Holloran et al. 2010; Green et al. 2017). Minimizing impacts to the core areas is not enough to mitigate for the adverse effects of energy development. Studies have found that Wyoming's core areas do not incorporate critical winter habitat for local populations (Smith et al. 2016). Therefore, protective

measures need to extend beyond the core areas to incorporate seasonal habitats as well as the pathways needed to access these habitats.

Cumulative Impacts 2015-2019

55. Utilizing the analysis described above, Figure 10 and Table 5 below show the cumulative impacts to the sage-grouse landscape from wildfire and energy development since adoption of the 2015 Sage-Grouse Plans. The core areas in Wyoming, Idaho, and Nevada are particularly at risk, having experienced large wildfires and increasing threats from energy development in just over three years.

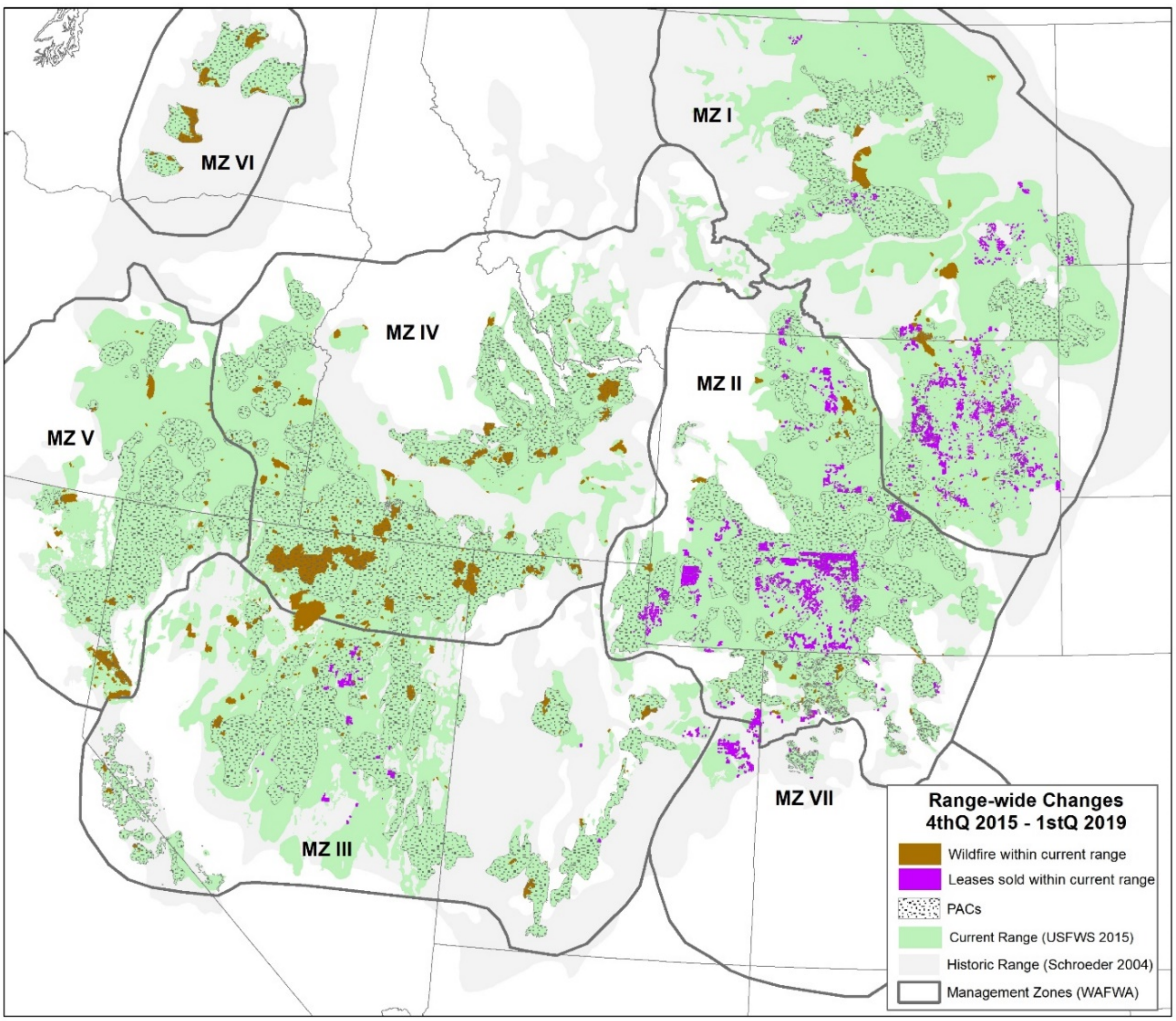

Figure 10. Wildfire and energy leases sold in sage-grouse habitat since September 2015.

4th Q 2015 – 1st Q 2019 Range-wide Changes					
MZ	Wildfire (Ha)		Oil/Gas Lease Sales (Ha)		
	Current Range	PACs	Offered Current Range	Sold Current Range	Sold PACs
I	192,816	29,756	495,430	328,404	109,655
II	91,177	32,445	1,095,878	573,881	287,357
III	209,290	113,714	712,694	65,801	30,503
IV	1,022,898	746,706	1,920	0	0
V	180,905	76,690	0	0	0
VI	141,777	1,414,443	0	0	0
VII	520	54	123,914	62,793	696
Total	**1,839,383**	**1,140,808**	**2,443,195**	**1,031,144**	**428,211**

Table 5. Summary of sage-grouse habitat impacted by wildfire and energy leases.

56. Since there has been no overlap between lands impacted by wildfire and those now marked for oil and gas development, the impact from these two factors is additive. Range-wide nearly three million hectares (over 7,000,000 acres) of currently occupied habitat, including almost 1.6 million hectares (over 3,800,000 acres) of priority habitat, have had a change of status since adoption of the 2015 Plan. This represents 5% of the priority habitat as defined by the PACs. A significant loss in just three years.

2019 Resource Management Plan Amendments

57. I have reviewed the BLM's December 2018 Final Environmental Impact Statements (FEISs) and March 2019 Records of Decision for BLM's amendments to the 2015 Sage-Grouse Plans in Idaho, Wyoming, Colorado, Utah, Oregon and Nevada/NE California. The BLM has not yet published any spatial data in association with the six amended plans from 2019, so my analysis of the impacts from these changes on the range-wide conservation portfolio for sage-grouse is based on the FEIS' descriptions of the regulatory changes and the implications for sage-grouse habitat, including the cumulative effects sections in the FEISs.

58. I am shocked and concerned to see that BLM's 2019 Plan Amendments purport to be based on the environmental analysis in the 2015 Plans, and that BLM asserts that "no new information has been identified that would invalidate or change the results of the existing analysis." *See, e.g.,* Utah 2018 FEIS at 4-4; Wyoming 2018 FEIS at 3-1 ("While the BLM acknowledges that there have been changes to the landscape since 2015, … data collected consistently across the range indicate that the extent of these changes to the landscape are relatively minimal"). In my opinion, this statement is both false and irresponsible, as significant changes in sage-grouse habitats have occurred in just the last three years, as documented above.

59. I was also concerned by BLM's failure to assess the conservation value of peripheral sage-grouse populations and habitat. For example, in discussing the impacts of the elimination of GHMA in Utah, BLM asserts that "there would be no significant effect of accelerating the impacts on the small populations in former GHMA[.]" *See* Utah FEIS at 4-21. This statement fails to consider that peripheral sage-grouse populations and habitats help ensure the species continues to exist by contributing to redundancy, representation, and resilience. *See* U.S. Fish and Wildlife Service, Greater Sage-grouse (*Centrocercus urophasianus*) Conservation Objectives: Final Report (Feb. 2013) ("COT" Report), at 12-13. As explained above, recent studies have also emphasized the importance of the landscape outside of PHMA as stopover habitat for long-distance migrants and corridors to seasonal habitats (Newton et al. 2017; Crist et al. 2015) as well as pathways for genetic connectivity and dispersal from population centers to low population areas around the range margins (Cross et al. 2018; Heinrichs et al 2018; Row et al. 2018). These surrounding habitats are also important for the preservation of conservation options as environmental conditions change (Burkhalter et al. 2018). BLM's FEISs failed to consider these values provided by GHMA and other non-priority habitats.

60. I also disagree strongly with the "cumulative effects" analysis provided by BLM in the December 2018 FEISs, which is quite short and cursory in each EIS, and fails to adequately address the recent losses and fragmentation of habitat as shown above, or consider the cumulative and synergistic impacts of other threats, particularly major new energy development and infrastructure siting (wind farms, powerlines, etc.) that are planned or pending.

61. Range-wide, the 2019 BLM Plan Amendments fail to account for the adverse changes that have occurred in priority sage-grouse habitat since 2015, and are a significant weakening of the 2015 Plans. The elimination of Sagebrush Focal Areas (SFA) in all of the states (except Montana and Oregon) weakens the protection of important habitats in some of the areas where it is needed most.

62. In Idaho, nearly all of the PACs incorporated some SFA designations. Referring back to Figure 2, we see that the PACs in the northeastern portion of the Idaho range contain unique habitats that contribute to representation within the portfolio and have largely been designated as an SFA. Downgrading management of these areas to Priority Habitat Management Areas (PHMA) increases their vulnerability to adverse resource development activities. Similar situations exist at the Utah-Wyoming and Oregon-Nevada borders where PACs identified in the portfolio analysis as containing unique habitats and given an SFA designation will now lose that protection.

63. The largest of the PACs which straddles the Idaho-Nevada border was given an SFA designation for much of its extent. As previously discussed, the western extent of this PAC is particularly susceptible to wildfire, primarily driven by the spread of cheatgrass. Loosening of the SFA protections on surface disturbances in conjunction with a weakening of the habitat objectives for livestock grazing will exacerbate the cheatgrass invasion leading to more

wildfires. Maintaining connectivity across this large landscape is critical for long-term population persistence within the region as fires increase.

64. In Wyoming, loss of the SFA protections in conjunction with a weakening of mitigation requirements and design feature standards across all sage-grouse habitat is problematic not only for the breeding populations within the PACs but also for the lands in between designated as General Habitat Management Areas (GHMA). Sage-grouse need to be able to move between areas not only to access seasonal habitat outside of PACs but also to disperse to new breeding sites as they are increasingly displaced by energy development.

65. All of the PACs wholly contained within Utah are significant from a habitat diversity perspective. The state has experienced a significant loss of sage-grouse habitat such that most of the current range within Utah has been incorporated into a few disjunct PACs. With the exception of the Sheeprocks PAC in the middle of the state, the remainder satisfy both the size and breeding density criteria for redundancy. These sites were never classified as SFA so they are not affected by that change. However, the weakening of other regulatory standards increases their vulnerability to habitat changes and their isolation from other PACs means that the long-term persistence of these populations is questionable.

66. A similar situation exists in northwest Colorado where numerous small PACs encompassing unique habitats along the range margin are at increased risk from energy development and other activities that may displace resident populations. Maintaining pathways between these PACs and across lands designated as GHMA to other areas of suitable habitat is essential.

Summary of Key Findings

Following is a synopsis of the key findings from my range-wide analysis:

65. The 301 PACs capture 96% of the moderate and high concentration breeding areas for sage-grouse and they support critical elements for representation, resilience, and redundancy. However, this network of priority areas has some significant weaknesses from a range-wide perspective.

- The network is highly dependent on a few large centrally located areas – over 80% of the PACs are less than 100,000 hectares in size, many of which do not support all of the seasonal habitats needed by resident populations.

- Many historically available habitat types are not represented within the PACs, particularly around the range margins and at lower elevations. Loss of habitat diversity constrains habitat selection opportunities and the capacity of sage-grouse to adapt to changing environmental conditions.

- Over 60% of the PACs have a low resilience to wildfire. The largest PAC within the network straddles the Idaho-Nevada border and is in an area experiencing a rapid expansion of cheatgrass and increasing wildfires. This area was classified as resilient only because of its size and diverse terrain which may mitigate some of the wildfire effects and allow populations to move when a fire occurs and recolonize the habitat once it has recovered. If the internal pathways allowing for this movement are severed, the region will lose its resilience as the isolated patches and associated populations are lost to wildfire.

- Management Zones VI (Columbia Basin) and VII (Colorado Plateau) lack redundancy. These zones have only one priority area each that is larger than 60,000 hectares and supports a moderate breeding density.

67. The 2015 Sage-Grouse Plans do not provide adequate protection for priority areas. Only 54% of the land within the priority areas is reclassified by the plan amendments.

Over 20% of the new classifications within the PACs provide very little protection. The public lands outside of the PACs but within the occupied range are similarly afforded very little protection from adverse activities. Given the small isolated nature of many of the priority areas, particularly around the range margins, the occupied habitat outside of the PACs is important for meeting seasonal requirements, connectivity for genetic exchange, and as refugia from disturbance events.

68. Wildfires are continuing to increase in frequency and intensity across the range, particularly within the central core habitat of southern Idaho, northern Nevada, and southeastern Oregon. Nearly 2 million hectares of sage-grouse habitat has burned in the last three fire seasons, including over 1 million hectares of priority habitat. The long-term persistence of populations in these regions necessitates the preservation of connectivity within and between areas of suitable habitat and the limitation of activities that contribute to the spread of invasive species, particularly cheatgrass.

69. The Wyoming Basin has thus far been only minimally affected by wildfires. However, it is being heavily impacted by oil and gas development with new leases frequently issued within occupied habitat, including priority areas. In less than four years the BLM has offered leases on nearly 2.5 million hectares of sage-grouse habitat, 45% of which is within the Wyoming Basin Management Zone. Leases from these offerings have been sold on over one million hectares of habitat, nearly half of which is within a PAC.

70. The 2019 Plan Amendments weaken the already limited protections of the 2015 plans and they fail to account for the habitat that has been lost to wildfire since the 2015 plans were adopted. They also fail to address the threats posed to the one million hectares of habitat that has been leased for oil and gas development since the end of 2015.

71. Implications for the range-wide conservation portfolio from the weakening of habitat protections in the 2019 Plan Amendments include:

• Exacerbate wildfire risks in fire-prone areas through weakening of livestock regulatory measures and increasing potential for spread of cheatgrass. Small priority areas may be lost in their entirety while larger areas that contain fire prone landscapes will lose their resilience if fragmented by development activities.

• Further contraction of range to center core areas as small isolated priority areas around the range margins are irreparably changed resulting in the loss of unique habitats and reduced range-wide habitat diversity. This is particularly problematic in areas with limited redundancy.

• Loss of connectivity between priority areas and to seasonal habitats outside of priority areas, will increase isolation and vulnerability of resulting island habitats and populations. This is particularly problematic in Wyoming where industrialization of sage-grouse habitat from energy development is occurring at an alarming rate.

72. The 2019 BLM Plan Amendments thus represent a disturbing and major step away from the protection of sage-grouse populations and habitats on BLM lands. I believe that imminent and irreparable harms can occur in the near future under the 2019 Plan Amendments, in allowing substantial new energy development and other human actions to further intrude upon, and degrade or fragment sage-grouse habitats. While the 2015 Plans themselves are probably not adequate to ensure the conservation of adequate sage-grouse habitats and populations to avoid risks of further declines toward extinction, the existing protections of the 2015 Plans should not be jettisoned and I recommend the Court keep the 2015 Plans in place until better plans are adopted, consistent with the best available science on sage-grouse conservation.

I declare under penalty of perjury pursuant to the laws of the United States that the foregoing is true and correct. Executed this 16th day of April, 2019 at Boise, Idaho.

Amy Haak

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Conservation Portfolio of Greater Sage-Grouse Core Habitat

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Abstract

Management strategies that increase biological diversity provide a hedge against uncertainty as global warming drives rapid environmental change and destabilizes ecosystems. For a landscape-scale species such as the Greater Sage-Grouse, these sudden changes are exacerbated by a history of anthropogenic impacts across much of their historical range that threatens their long-term ability to adapt and persist. The Fish and Wildlife Service has defined 301 Priority Areas for Conservation (PACs) across the occupied range. These sites are intended to capture the core habitats critical to the survival of remaining sage-grouse populations. The 3-R framework of *representation* (unique or rare elements of diversity), *resilience* (the ability to recover from a disturbance), and *redundancy* (having a sufficient number of representative elements so that some can be lost without jeopardizing the whole) is used to compare the range-wide conservation portfolio as represented by the PACs with the historical portfolio. Although the PACs capture 96% of the moderate to high concentration breeding areas and are well distributed across the currently occupied range, there are significant weaknesses within the portfolio. Many historically available habitats are not represented within the PACs, particularly around the range margins and at lower elevations - only 27% of the priority areas are below 1,500 meters compared to 52% of the historical range. Of the 108 PACs contributing the most to representation, 56 have low resilience to wildfire and fail to meet the size and breeding density criteria for redundancy.

INTRODUCTION

One of the basic tenets of conservation biology is that biological diversity provides stability (Primack 2002). Biologically rich systems can more easily withstand disturbance and swings in environmental conditions that would destabilize communities dominated by few species or species dominated by only a few small populations. The ability of diverse natural systems to maintain their function and productivity in the face of rapid environmental change has been termed the 'portfolio effect', a concept analogous to the desire among financial managers to maintain a diverse economic portfolio as a hedge on uncertain futures (Figge 2004). A diversified portfolio seeks to optimize the mix of assets associated with different risk classes in order to provide a hedge against catastrophic conditions. There is no exact quantitative measure for a balanced portfolio but rather it is evaluated along a continuum from historical levels of diversity to current or future conditions – the more elements of historical diversity that are still present today, the more balanced the portfolio and the more stable the community.

Species-based conservation plans based on habitat suitability models that identify high priority conservation targets often fail to account for rare habitats and populations along the margins that have been lost or diminished to a greater extent than the core areas. This is particularly problematic for landscape-scale species with behavioral strategies and adaptations that historically enabled individuals to disperse and exploit a variety of habitats across diverse landscapes. Populations occurring in marginal and unique habitats found at the periphery of a species' range often contain a disproportionate percentage of the species' genetic variation and evolutionary potential for adaptation (Araujo and Williams 2001, Hampe and Petit 2005, Haak et al. 2010). Since species' ranges tend to contract towards the center, conservation plans based solely on remaining core habitats risk omitting critical elements of diversity from around the edges with potentially negative consequences for the species' ability to adapt to rapid environmental change. Plans that encompass historical levels of diversity range-wide will produce a more balanced conservation portfolio (Haak and Williams 2013).

The Greater Sage-grouse (*Centrocercus urophasianus*, hereafter sage-grouse) exemplifies a well-studied landscape-scale species of conservation concern. Historically, an estimated 16 million sage-grouse were found in 15 western states and three Canadian provinces. Sage-grouse have been extirpated in four states and one Canadian province and now occupy about one-half of their historical extent (Schroeder et al. 2004). They have been a conservation concern since the 1950's when the Western Association of Fish and Wildlife Agencies (WAFWA) agreed to monitor sage-grouse and develop management strategies. Conservation efforts escalated in the 1990's when population estimates showed a consistent downward trend. Since then there have been seven petitions to protect sage-grouse pursuant to the Endangered Species Act (Knick and Connelly 2011) and innumerable studies and conservation plans. Between 2015 and 2017, there were 99 new publications related to habitat suitability for sage-grouse and another 99 addressing sage-grouse population dynamics and genetics (Hanser et al. 2018).

Sage-grouse are a sagebrush obligate, dependent on access to large expanses of healthy and diverse sagebrush communities throughout the year. *Sagebrush* (genus *Artemisia*) is the common term for the vast expanse of shrublands covering the semi-arid regions of the Intermountain West from the Columbia Basin to the Great Basin, Colorado Plateau and Great Plains. Sagebrush occur in two general life forms: low and tall. The low form contains eight different species while the tall form contains four. Of these four, big sagebrush (*Artemisia tridentata*) is the most prevalent with five known subspecies. Sagebrush landscapes are a mosaic of habitats encompassing shrublands, grasslands, wet meadows and a diverse understory of native forbs and bunch grasses. The structure and composition of these plant communities vary across the landscape due to differences in soils, climate, topography, and other physical processes resulting in a variety of habitats and disturbance regimes.

Sage-grouse currently occupy about 670,000 km^2. Within that expanse there are at least 11 species of sagebrush with varying structure, productivity, and chemical composition that contribute to different levels of resistance and resilience to disturbance. Sage-grouse have evolved to take advantage of these diverse sagebrush communities both spatially and temporally. They utilize a variety of plants over the course of the year to support different life history stages and may migrate over 20 km between two or three distinct seasonal ranges to satisfy their complex habitat selection criteria (Connelly et al. 2011). Mesic resources are particularly important for brood rearing (Donnelly et al. 2016) while access to big sagebrush is critical for winter survival in areas of high snowfall (Smith et al. 2016).

Changes to the sagebrush landscape have left sage-grouse populations isolated on shrinking islands of habitat where they are often unable to access the full range of plant communities upon which they depend. Over the last two centuries sagebrush landscapes have experienced significant conversion, degradation and fragmentation from urban development, agricultural expansion, livestock grazing, and mining, particularly in valley bottoms and on productive lands. Anthropogenic impacts across sage-grouse habitat have increased over the past four decades as population growth has accelerated in the Intermountain West (Leu and Hanser 2011). Over the past decade, the rapid and expansive development of oil and gas reserves has further fragmented and degraded the sagebrush landscape to the detriment of local sage-grouse populations (Holloran et al. 2010, Green et al. 2017).

On March 23, 2010 the U.S. Fish and Wildlife Service (FWS) determined that the listing of sage-grouse pursuant to the Endangered Species Act was warranted but precluded by other priorities so sage-grouse became a candidate species for federal protection. This decision led to the formation of the Conservation Objectives Team (COT) comprised of state and FWS representatives. In 2013 the COT identified 301 Priority Areas for Conservation (PACs) which were then adopted by the FWS. Although the PACs encompass just 43% of the currently occupied habitat, the National Technical Team (NTT) states that these areas represent '…the highest conservation value to maintaining or increasing sage-grouse populations … [and] would include breeding, late brood rearing, winter concentration areas, and where known, migration or connectivity corridors.' Management of the PACs is intended to prioritize the protection of sage-grouse while the lands outside of the PACs is subject to normal land uses.

In their connectivity analysis of the 301 PACs, Crist et al. (2015) describe the network as a 'grand experiment in conservation biology and reserve design.' The PACs range in size from 4 hectares to over 5.3 million hectares and are distributed in a highly centralized network. The dependence on a few large centrally located priority areas for connectivity leaves the network vulnerable to collapse should any of the critical areas or pathways be lost. While maintaining pathways to low population areas around the range margins is important for long-term genetic exchange (Cross et al. 2018), these sites often fall through the cracks as the designation of core areas tends to emphasize high density breeding habitat (Smith et al. 2016).

Recent studies have found that the population response to breeding habitat varies across the occupied range, indicating that habitat selection is more complex than simply the presence of sagebrush (Doherty et al. 2016). Loss of diversity may constrain habitat selection and the capacity of sage-grouse to adapt to changing environmental conditions. The objective of this analysis is to analyze the conservation portfolio of the priority area network for sage-grouse from the perspective of historical habitat diversity. The 3-R framework of representation, resilience, and redundancy is used to describe the portfolio defined by the 301 PACs. This analysis is not intended to replace detailed site-specific assessments of sage-grouse priority areas but rather to determine how well the range-wide conservation network captures historical elements of diversity. If PACs are to provide the final safety net for remaining populations of sage-grouse, they should encompass the historical attributes of diversity and connectivity that once enabled sage-grouse to flourish.

METHODS

The analysis of the 301 priority areas encompasses the historical range for sage-grouse within the United States. Historical habitat and remaining populations within Canada were not included due to a lack of available data. This is a landscape-scale analysis that utilizes published spatial data sets encompassing the entire historical range. While more detailed data is available for specific areas, this information was not included since it would bias the results. Data on habitat quality and suitability were not included based on the assumption that these factors were already taken into account in designating the priority areas.

Describing the conservation portfolio for sage-grouse as represented by the PACs requires a comparison with historical diversity to establish a baseline for assessing change both spatially and temporally. The spatial data set developed by Schroeder et al. (2004) defines the historical range used in the portfolio analysis. Figure 1 shows the delineation of the historical range and PACs used in the analysis described herewith. In delineating the PACs, the FWS associated them with 32 populations and metapopulations represented by different colors on the map. These are shown for reference purposes only since the following analyses are based on the characterization of individual PACs. The sage-grouse Management Zones (MZ) developed by WAFWA (Western Association of Fish and Wildlife Agencies) represent broad floristic regions and are used to stratify results of the 3-R analysis.

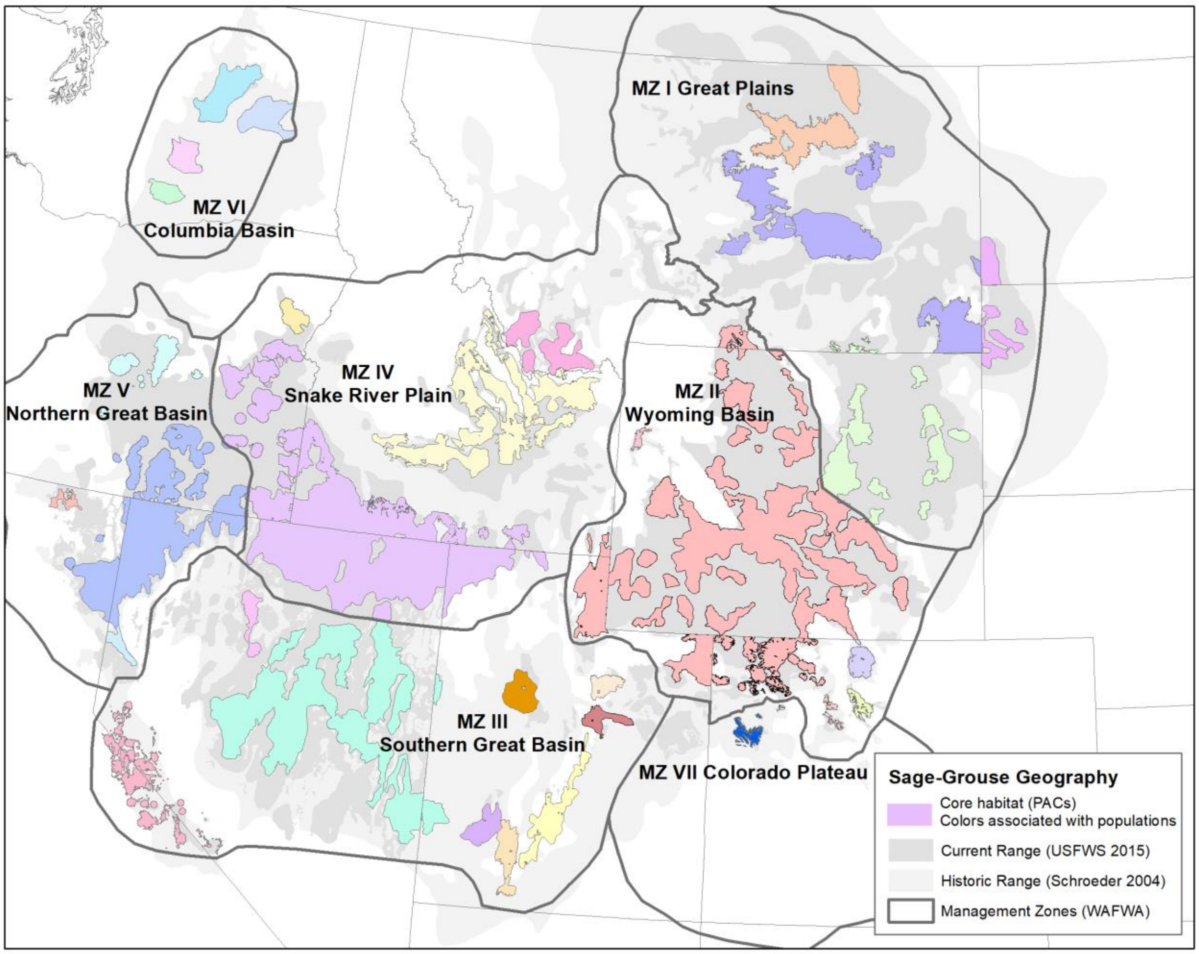

Figure 1. Distribution of USFWS PACs associated with USFWS defined sage-grouse populations.

The PAC-based conservation portfolio can be assessed using the 3-R framework of *representation* (conserving diversity), *resilience* (having large intact habitats and populations to facilitate recovery from disturbance), and *redundancy* (saving multiple geographically dispersed populations and habitats so that some can be lost without jeopardizing the species) (Shaffer and Stein 2000, Haak and Williams 2012). This framework is grounded in the science of conservation biology and has been adopted by the U.S. Fish and Wildlife Service in developing recovery plans for threatened and endangered species (Carroll et al. 2006).

In 2013 the U.S. Fish and Wildlife Service released a peer-reviewed report of the Conservation Objectives Team (COT) that describes range-wide conservation objectives for sage-grouse. Section 4 of the COT Report describes their *Conservation Framework* stating that *'[w]e used three parameters – population and habitat **representation, redundancy, and resilience*** [emphasis added] … *as guiding concepts in developing our conservation goal, priority areas for conservation, conservation objectives, and measures*.' (U.S. Fish and Wildlife Service 2013, p. 12).

Of particular relevance to this analysis is the application of the 3-Rs to habitat as well as populations and the emphasis placed on '…*conserving well distributed sage-grouse populations across **geographic and ecological gradients*** [emphasis added] …' (U.S. Fish and Wildlife Service 2013, p. 12). This underscores the importance of preserving unique habitats beyond the core areas in order to preserve the adaptive capacity of the species across its range.

Representation

The representation portion of the portfolio analysis compares habitat diversity across the historical range of sage-grouse to the priority areas to determine how well these 301 sites capture the array of historical habitats once available to sage-grouse. The biological premise is that populations of a species evolve to take advantage of site-specific habitat conditions which may vary across a species' range. When populations and habitats in these disparate geographies are lost, the species' overall adaptive capacity is diminished. Similarly, access to diverse habitats and plant communities provides a hedge against population declines due to seasonal and annual variability in food sources.

The objective of the representation analysis is to highlight the unique/rare habitats that are important to the preservation of range-wide diversity. A habitat type is considered rare if it was rare historically (e.g. peripheral habitats) or has experienced a disproportionate reduction in extent when compared to other habitat types. This analysis uses a multi-scaled evaluation of habitat types across the historical range of sage-grouse to quantify the diversity that has been lost and highlight those remaining habitat types that are the most vulnerable due to their limited extent.

The representation analysis does not utilize existing vegetation data since this would preclude a comparison to range-wide historical conditions. Instead this analysis characterizes habitat based on the integration of biotic and abiotic factors across environmental gradients without anthropogenic influences, thus allowing for historic comparisons. The use of hierarchical scales allows for the identification of large landscapes as well as local habitats not represented in the PACs. Specifically, the four habitat-based data layers used in this analysis are: Sage-grouse Management Zones, Level III Ecoregions, Level IV Ecoregions, and elevation.

The management zones are the broadest delineation, representing seven distinct floristic regions across the historical extent. Ecoregions were developed by the U.S. Environmental Protection Agency to describe areas where ecosystems are generally similar. They were developed through the integration of factors such as geology, landforms, soils, vegetation, climate, wildlife, and hydrology. They are frequently used by federal and state agencies for structuring ecosystem management strategies. They have been developed in hierarchical levels ranging from broad regions (i.e. Level I with 12 ecoregions in the continental U.S.) to more detailed regions (i.e. Level IV with 967 ecoregions in the continental U.S.). There are 23 level III and 240 level IV ecoregions within the historical range of sage-grouse. Use of Level III and IV ecoregions allows for a multi-scaled assessment of changes in available habitats. And finally, a digital elevation model (DEM) was used to characterize how well the PACs reflect the historical distribution of sage-grouse habitat across topographic gradients.

Each of these four habitat delineations were summarized by MZ for the historical range and priority areas. These summations were used to identify habitats that have been lost, as well as those that were rare historically or have experienced a reduction that is disproportionate to the overall range contraction and thus represent the more vulnerable conservation elements within the range-wide portfolio. For the purpose of this analysis, those habitat types that comprise less than 5% of the historical range were highlighted for historical rarity and those types occurring within the PACs at less than 10% of their historical extent were highlighted for being at risk. The cumulative area of unique/rare habitat types was calculated for each priority area as a percentage of the total PAC area to highlight those PACs encompassing the greatest concentration of under-represented habitats.

Resilience

Resilience is the ability of a population, habitat, or ecosystem to regain its function after a disturbance event. It is particularly important in this era of climate change with drought and wildfires increasing in frequency and intensity across much of the western United States, a situation that is exacerbated by factors such as the spread of cheatgrass and anthropogenic impacts that stress and alter natural processes (Chambers et al. 2017). Table 1 provides decadal summaries from 1984-2017 of the number of fires, maximum size, and total area burned across the historical range of sage-grouse. While the near doubling of the number of fires is alarming, the fivefold increase in the number of large fires (over 100,000 acres) from the decade 1984-1993 to 2004-2013 is particularly troubling for the future of sage-grouse in these fire prone ecosystems.

Years	Number of Fires	Largest Fire (acres)	Total Area Burned (acres)	Number of Fires Over 100,000 acres
1984-1993	793	228,161	6,059,419	6
1994-2003	1,430	236,451	13,313,852	15
2004-2013	1,324	567,409	16,571,252	33
2014-2017	1,292	646,452	7,580,338	15

Table 1. Fire statistics for the historical range of sage-grouse. Summaries based on fire perimeter data developed by the Geospatial Multi-Agency Coordination Group (GeoMAC).

Given the growing threat of wildfire to sage-grouse habitat and the challenges of effective mitigation and restoration, a network of priority areas should encompass areas that have some inherent resilience to wildfire. Local and regional biotic and abiotic factors influence how a wildfire moves across the landscape as well as the post-fire recovery. Landscapes with diverse topography and native vegetation will likely result in a spottier burn pattern than more homogenous sites where a fire can burn unimpeded. Post-fire recovery in the patchy burn areas is facilitated by the proximity of native seed sources while areas at the center of a uniform burn may not be able to reseed naturally. However, where cheatgrass is present it is difficult to prevent its expansion into newly burned sites regardless of the burn pattern.

For the purposes of this analysis, resistance and resilience to wildfire is evaluated for the PACs using five variables: resistance to cheatgrass, topographic diversity, 1984-2017 area burned, patch size, and connectivity. The first three factors address a site's inherent resistance to wildfire while patch size and connectivity are important for post-fire recovery. Large, well-connected habitats with minimum cheatgrass will fare the best during and after a wildfire.

Resistance to cheatgrass is based on the Ecosystem Resilience and Resistance data layer developed by Chambers at al. (2017). The authors used data from the soil survey on soil temperature and moisture regimes to depict ecological resistance to cheatgrass invasion across the historical range of sage-grouse. Their assumption being that cool/wet sites are more resistant to cheatgrass and thus more resilient to fire than warm/dry sites. Their results are ranked on a scale of 0 (wetlands) – 3 (hot and dry). These rankings were reclassified on a scale of 1-4 with 1 representing the lowest resistance and 4 being the highest. Topographic variability can help mitigate the effects of a wildfire by providing different slopes, aspects, vegetation, and micro-climates that may slow the spread of a fire, change its direction, or reduce the burn intensity in some areas. To assess this factor the standard deviation of elevation was calculated across the historical range using a 5 km x 5 km moving window. The results were reclassified into four bins using the Jenks natural breaks classification - a data clustering method that seeks to minimize the variance within classes and maximize the variance between classes. A value of 1 has the least topographic diversity and therefore highest risk while a value of 4 is the most diverse.

The burn history data from 1984 – 2017 summarized in Table 1 was converted to a raster data set and reclassified into four bins: 1: burned 3 or more times; 2: burned twice; 3: burned once, 4: has not burned. The assumption being that burned areas are more likely to have altered plant communities including annual grasses such as cheatgrass that will decrease their resilience to future fires. Areas that have burned multiple times are likely to continue burning at a greater frequency as cheatgrass and other annuals spread. The three grids were then summed (i.e. burn history, topographic variability, and cheatgrass resistance) across the current range and a mean value of wildfire risk was calculated for each PAC.

Natural recovery from a wildfire requires a source for native seeds and the opportunity for recolonization by native wildlife from invertebrates to mammals. In addition to the pattern and severity of the burn, natural recovery is influenced by the surrounding landscape. Larger intact patches are less likely to burn in their entirety and can support the revegetation and recolonization of native species within the patch. Small interconnected patches may also facilitate natural recovery if some of the patches are left unburned. However, small isolated patches susceptible to area-wide burns may not recover without management intervention to replant and reintroduce native species.

Patch size and connectivity were used to assess the relative potential for post wildfire recovery of the PACs. The PACs were grouped into four size classes using the Jenks natural breaks classification: 1: less than 150,000 ha; 2: 150,000 – 500,000 ha; 3: 500,000 – 1,000,000 ha; and 4: more than 1,000,000 ha. Connectivity was based on the analysis of Crist (2015) in which the authors calculated the betweenness centrality for each of the PACs – a measure indicative of the connectivity of each PAC to other PACs across the range. The PACs with higher centrality values are the most important to the larger network in terms of connectivity. PACs with low values are more isolated with few if any other PACs connecting to them. The PACs were grouped into four classes based on their centrality values with 4 representing the highest betweenness centrality values. These two attributes (i.e. patch size and connectivity) were combined to provide a ranking of priority areas for post-fire recovery. This measure was added to the results of the wildfire risk analysis to highlight those priority areas with the greatest wildfire resilience.

Redundancy

Redundancy serves as the final safety net within the range-wide portfolio. Ideally a diverse array of large, intact and resilient habitat patches will be well-distributed across the sage-grouse range. In regions where the remaining habitat is in small fragmented patches, redundancy insures that some populations and habitats will persist, even after a local loss from a stochastic event or human related activity.

The redundancy analysis is assessed for the Management Zones with the goal of having multiple priority areas within each zone that are capable of supporting a population of sage-grouse. This insures that the unique characteristics associated with each zone are not lost to a single disturbance. For the purposes of this study it is assumed that the PACs represent high quality habitat suitable for sage-grouse. However, many of the PACs are very small and function merely as stepping stones between larger patches and are not likely to support a population if a disturbance event were to isolate them from the other PACs. Therefore, a patch size criterium is needed to identify those PACs that have the greatest potential for continuing to support a population of sage-grouse following a disturbance event. Recognizing that the annual home range requirements for an individual may vary from 4 – 615 km^2 due to seasonal behaviors and habitat requirements (Connelly(b) et al. 2011) and migratory populations (e.g. Northern Great Plains population) may utilize over 5,000 km^2 moving between critical seasonal habitats (Newton et al. 2017), a patch size criterium of 600 km^2 was applied. While not large enough to encompass the habitat requirements of long-distance migrants, this patch size should satisfy the home range requirements for resident populations, assuming seasonal habitat needs are met within the patch.

In addition to size, it is also important for a PAC to support a breeding concentration area that can sustain a population should adjacent patches and populations be lost. For this we rely on the breeding density as characterized by Doherty et al. (2011). Figure 2 shows the breeding density across the current range. The areas classified with a 25% breeding density are the most concentrated breeding centers while 100% breeding density represents the least concentrated. (The categories indicate the minimum amount of land area required to incorporate 25%, 50% etc. of the breeding population such that the lower numbers correspond to more concentrated breeding areas.) The PACs capture 96% of the highest concentration breeding sites (i.e. 25% and 50%.) range-wide. The highest breeding density was determined for each PAC and those PACs with only the lowest concentration (i.e. 100% breeding density) were classified as not contributing to redundancy.

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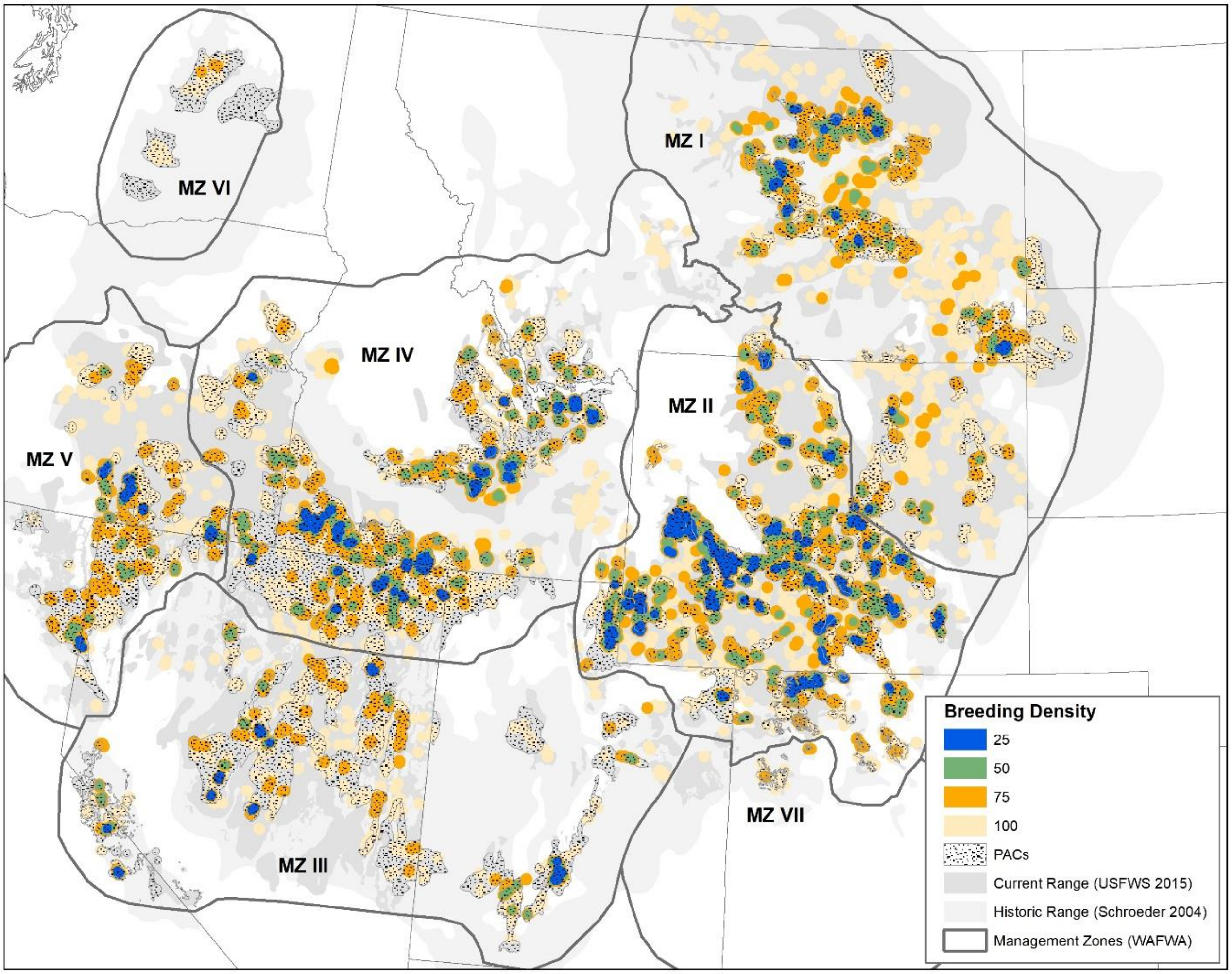

Figure 2. Breeding concentration areas across the current range (Doherty et al. 2011).

Results

Representation

Sage-Grouse Management Zones

Table 2 provides a summary of available habitat by MZ for the historical range and priority areas. Overall the PACs encompass 28% of the historical range and all of the MZs, with the exception of VII, are above the 10% threshold. However, the distribution is shifting. Historically MZ I (Great Plains) comprised over 27% of the range-wide distribution but this has now dropped to just over 15% while MZ IV (Snake River Plain) has increased from 20.2% representation to 29.2%. Similarly, MZs II (Wyoming Basin) and V (Northern Great Basin) have also shown increases in range-wide representation while MZ III (Southern Great Basin) has declined. Management Zones VI (Columbia Basin) and VII (Colorado Plateau) are highlighted in red due to their historical rarity representing just 4.5% and 2.4% respectively, of the historical range. Management zone VII is of particular concern since only 3.5% remains of the already limited historical habitat putting it at less than 1% of the range-wide portfolio.

MZ	Historical Range		PACs			
	Hectares	Percent of Total	Hectares	Percent of Total	Percent of Historic	Number of PACs
I	30,354,753	27.1%	4,736,708	15.1%	15.6%	25
II	17,186,561	15.3%	6,930,204	22.1%	40.3%	106
III	24,786,277	22.1%	6,074,743	19.4%	24.5%	74
IV	22,672,166	20.2%	9,142,479	29.2%	40.3%	55
V	9,262,702	8.3%	3,269,662	10.4%	35.3%	19
VI	**5,065,623**	**4.5%**	**1,092,810**	**3.5%**	**21.6%**	**4**
VII	**2,673,616**	**2.4%**	**94,387**	**0.3%**	**3.5%**	**18**
Total	**112,001,699**	**100%**	**31,340,993**	**100%**	**28%**	**301**

Table 2. Extent of historical range and Priority Areas for Conservation (PACs) by Management Zone. Highlighted zones are historically rare and of conservation concern.

Level III Ecoregions

Level III ecoregions provide a spatial refinement to the MZ analysis with 17 ecoregions represented in the historical range that, when combined with Management Zones generates 35 unique habitat classes (Figure 3). Table 3 summarizes the relative contribution of each ecoregion to each MZ for both the historical range and the PACs. A comparison between the two shows the concentration of priority areas in well-represented habitats while the more geographically limited and unique areas historically are not well represented in the range-wide portfolio. Overall, eight of the 35 ecoregion/MZ combinations are no longer represented. Some ecoregions lost in one MZ are still present in another (e.g. Middle Rockies) while others such as High Plains and Cascades have been completely lost to the range-wide portfolio. In contrast, some of the dominant types such as the Wyoming Basin (MZ II) and the Northern Basin and Range (MZs IV and V) have increased their representation relative to historical levels.

The ecoregions highlighted in brown in Table 3 represent those types that were part of the historical range but have not been captured by the PACs. The nine ecoregion/MZs highlighted in red were rare historically (less than 5% of the historical range within each MZ) with three occurring at less than 10% of their already limited historical distribution. The two rows highlighted in blue represent regions that were more prevalent historically but have been diminished to less than 10% of their original extent. Both of these correspond to the Colorado Plateau ecoregion in MZs III and VII.

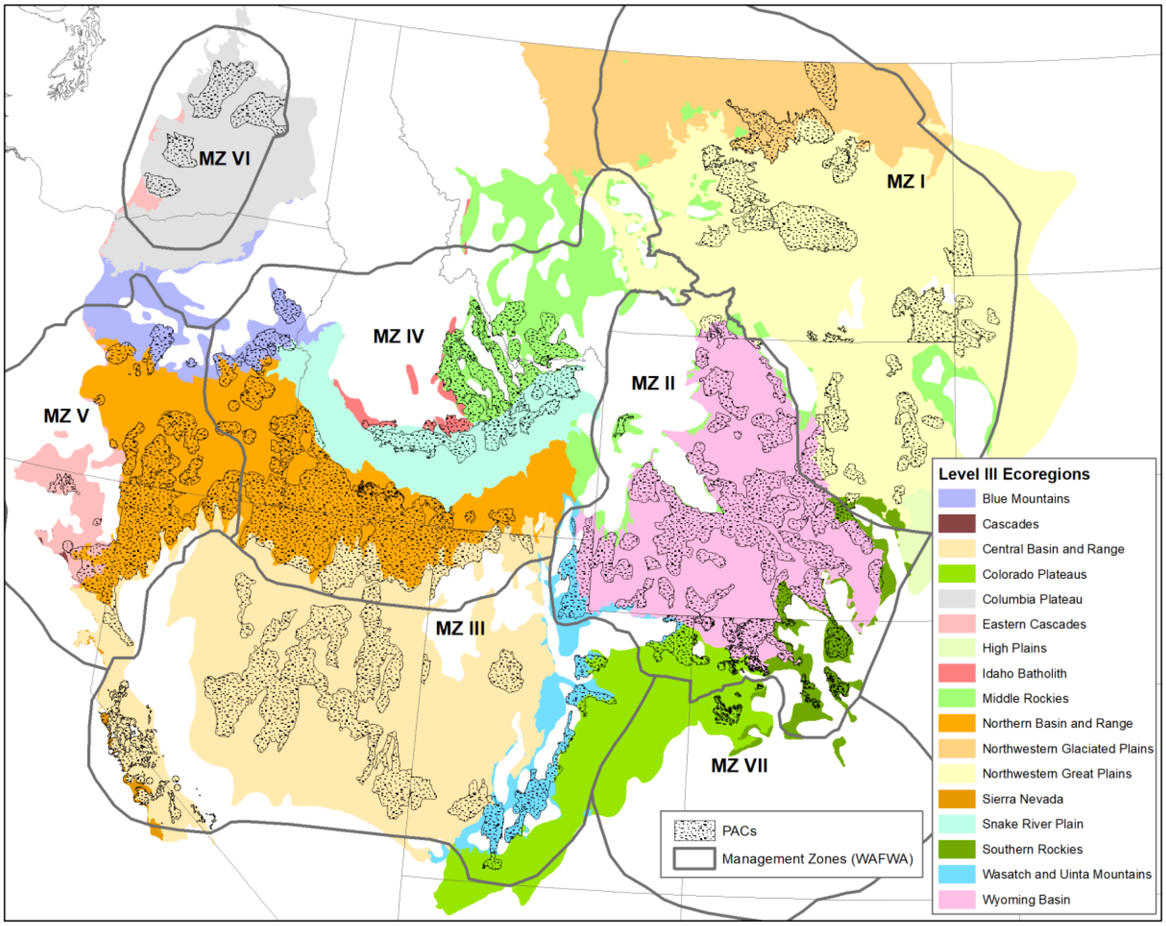

Figure 3. Level III Ecoregions across the historical range of sage-grouse and priority areas.

MZ	Level III Ecoregions	Historical Range (% MZ Total)	PACs (% MZ Total)	Percent of Historical
I	**High Plains**	**1.5%**	**0%**	**0%**
	Middle Rockies	**3.3%**	**0%**	**0%**
	Northwestern Glaciated Plains	22.7%	16.1%	11.1%
	Northwestern Great Plains	70.7%	79.6%	17.6%
	Southern Rockies	**0.6%**	**0.3%**	**7.6%**
	Wyoming Basin	**1%**	**3.9%**	**57.5%**
II	Colorado Plateau	6.5%	4.8%	29.5%
	High Plains	**1.1%**	**0%**	**0%**
	Middle Rockies	**3.4%**	**0.7%**	**9.0%**
	Northwestern Great Plains	**2.1%**	**0.8%**	**14.9%**
	Southern Rockies	9%	7.3%	33.0%
	Wasatch and Uinta Mountains	**3.3%**	**4.7%**	**56.7%**
	Wyoming Basin	74.5%	81.7%	44.3%
III	Central Basin and Range	80.1%	83%	25.4%
	Colorado Plateau	**12%**	**3%**	**5.3%**
	Sierra Nevada	**0.5%**	**1%**	**48.2%**
	Wasatch and Uinta Mountains	7.3%	13%	44.5%

IV	Blue Mountains	4.2%	4.7%	45.3%
	Central Basin and Range	11.1%	12.1%	43.8%
	Idaho Batholith	2.1%	1.8%	34.5%
	Middle Rockies	18.2%	16.9%	37.4%
	Northern Basin and Range	36.6%	52.5%	57.8%
	Northwestern Great Plains	4.8%	0%	0%
	Snake River Plain	22.9%	12.1%	21.3%
	Wasatch and Uinta Mountains	0.2%	0%	0%
V	Blue Mountains	12.9%	5.2%	14.4%
	Cascades	0.2%	0%	0%
	Central Basin and Range	9.5%	3.8%	14.0%
	Eastern Cascades Slopes and Foothills	17.1%	7.8%	15.9%
	Northern Basin and Range	60.2%	83.4%	48.9%
VI	Columbia Plateau	95.2%	100%	22.7%
	Eastern Cascades Slopes and Foothills	3.3%	0%	0.06%
	Northern Rockies	0.7%	0%	0%
VII	Colorado Plateau	92.6%	100%	3.8%
	Southern Rockies	7.4%	0%	0%

Table 3. Representation of level III ecoregions within the historical range compared to PACs by MZ. Ecoregions shown in brown are not represented in the PACS while those in red are historically rare (less than 5% historical representation within the management zone) and those in blue have been reduced by 90% of their historical extent.

Level IV Ecoregions

The level IV ecoregions represented across the historical range provide a more detailed overview of changes in habitat diversity. While a level III ecoregion may appear to be well represented, the more nuanced view provided by level IV ecoregions can highlight smaller habitats that may be falling through the cracks within the larger region. Table 4 summarizes the number of level IV ecoregions within each MZ and the current extent of those regions within the PACs. When combined with MZs the number of unique areas is 251 with MZ IV (Snake River Plain) exhibiting the greatest amount of historical habitat diversity (73 level IV ecoregions) and MZ VII (Columbia Basin) the least with just 10. (Recognizing the coarseness of the data set, habitat slivers within the historical range of less than 1,000 ha not represented in the PACs were deleted from the analysis).

Number of Level IV Ecoregions represented within each MZ					
MZ	Historical Range	PACs			
		Not represented	<10% of Historical extent	10-25% of Historical extent	>25% of Historical extent
I	38	14 (36%)	12 (32%)	6 (16%)	6 (16%)
II	39	10 (26%)	7 (18%)	6 (15%)	16 (41%)
III	44	9 (20%)	12 (27%)	3 (7%)	20 (46%)
IV	73	22 (30%)	18 (25%)	11 (15%)	22 (30%)
V	35	9 (25%)	10 (29%)	10 (29%)	6 (17%)
VI	12	5 (42%)	3 (25%)	0	4 (33%)
VII	10	7 (70%)	3 (30%)	0	0
Total	251	76 (30%)	65 (26%)	36 (14%)	74 (29%)

Table 4. Number of level IV ecoregions within the historical range compared to PACs by MZ.

Range-wide, 30% of the historical habitats are no longer represented within the PACs and another 26% are found at less than 10% of their historical extent making them a conservation priority for representation. Taken together, over one-half of the array of habitats available to sage-grouse historically are either not captured or are severely diminished within the designated priority areas. MZs II and III are the only zones in which over one-half of the habitat types are found within the PACs at greater than 10% of the historical extent. MZ VII is the most diminished with only 30% of the habitat types represented and all are at less than 10% of the historical extent.

Elevation

A digital elevation model (DEM) was used to evaluate changes in habitat distribution across topographic gradients from the historical range to the PACs. The DEM was reclassified into six discrete elevation zones across the historical range (Figure 4). Visually it is evident that many of the lower elevations found primarily in MZs I and VI have limited representation in the PACs. The loss of the low elevation Snake River Plain (MZ IV) is also evident as the PACs are associated primarily with higher elevation uplands. Range-wide there is a shift in available habitat from low-mid elevations to mid-high elevations. Historically 52% of the range was below 1,500 meters but with the disproportionate loss of low elevation habitat just 27% of the priority areas are found below 1,500 meters. Table 5 highlights those elevation zones that were historically rare (red) and those that have lost over 90% of their historical extent (blue).

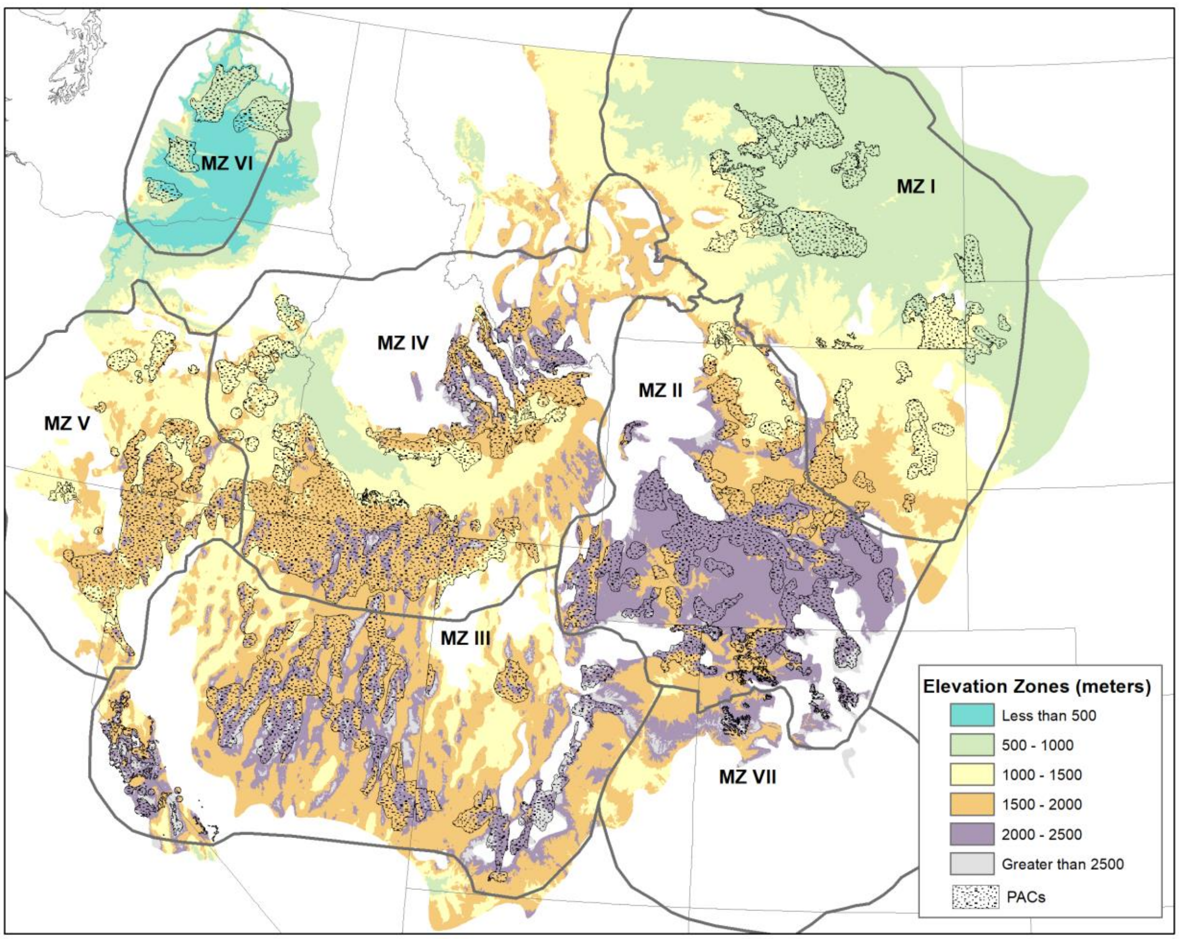

Figure 4. Elevation zones across the historical range of sage-grouse with PACs shown in a stipple pattern.

MZ	Elevation Zones (m)	Historical Range (Prct MZ Total)	PACs (Prct MZ Total)	Percent of Historical
I	500 – 1000	55%	59%	16.8%
	1000 - 1500	36%	31%	13.4%
	1500 - 2000	9%	10%	17.8%
	2000 - 2500	**<1%**	**<1%**	**8.7%**
II	**500 – 1000**	**<1%**	**0%**	**0%**
	1000 - 1500	10%	5%	18.1%
	1500 - 2000	29%	31%	42.4%
	2000 - 2500	55%	62%	45%
	Greater than 2500	**5%**	**3%**	**22.5%**
III	**Less than 500**	**<1%**	**0%**	**0%**
	500 – 1000	-	-	-
	1000 - 1500	**16%**	**<1%**	**0.6%**
	1500 - 2000	52%	46%	21.4%
	2000 - 2500	25%	42%	40.2%
	Greater than 2500	6%	12%	49.3%
IV	**500 – 1000**	**8%**	**1%**	**4.6%**
	1000 - 1500	33%	20%	24.7%
	1500 - 2000	46%	60%	52.6%
	2000 - 2500	12%	18%	59.8%
	Greater than 2500	**1%**	**1%**	**33.5%**
V	**500 – 1000**	**2%**	**0%**	**0%**
	1000 - 1500	52%	23%	15.7%
	1500 - 2000	42%	70%	58.7%
	2000 - 2500	**3%**	**6%**	**67.4%**
	Greater than 2500	**<1%**	**<1%**	**41.2%**
VI	**Less than 500**	**55%**	**21%**	**8.1%**
	500 – 1000	42%	78%	40.2%
	1000 - 1500	**3%**	**<1%**	**7.5%**
	1500 - 2000	**<1%**	**0%**	**0%**
VII	**Less than 500**	**<1%**	**0%**	**0%**
	500 – 1000	-	-	-
	1000 - 1500	19%	0%	0%
	1500 - 2000	39%	<1%	0%
	2000 - 2500	**34%**	**71%**	**7.4%**
	Greater than 2500	8%	29%	12.1%
Range-wide	Less than 500	3%	1%	6.3%
	500 – 1000	22%	12%	13.7%
	1000 – 1500	27%	14%	13.1%
	1500 – 2000	30%	42%	34.9%
	2000 – 2500	16%	28%	43.4%
	Greater than 2500	2%	3%	36.5%

Table 5. Representation of elevation zones within the historical range and PACs by MZ.

Identification of PACs Contributing to Representation

The representation analysis shows the concentration of the more broadly distributed habitat types in the priority areas while many of the habitats with a limited distribution historically are not adequately represented in the PACs. Figure 5 shows the relative importance of the PACs to range-wide representation based on the cumulative area within each PAC of all unique and/or under-represented habitats adjusted for PAC size. The PACs shown in dark green encompass the highest concentration of under-represented habitats. These areas are either wholly contained within one of the target elements or include multiple overlapping targets such that the cumulative area exceeds the total area of the PAC. The PACs shown in light green in Figure 5 also contain target habitats but at a lower concentration. The PACs in beige are comprised entirely of habitats that are well-represented within the priority area network. Table 6 provides a tabular summary of the number of PACs in each representation class by Management Zone.

Many of the highest priority areas from a representation perspective are found around the edges of the currently occupied range. This is not surprising given that the range margins are typically where unique habitats occur as individuals disperse to the edges of their suitable habitat, exploiting environments that differ from the centrally located core areas.

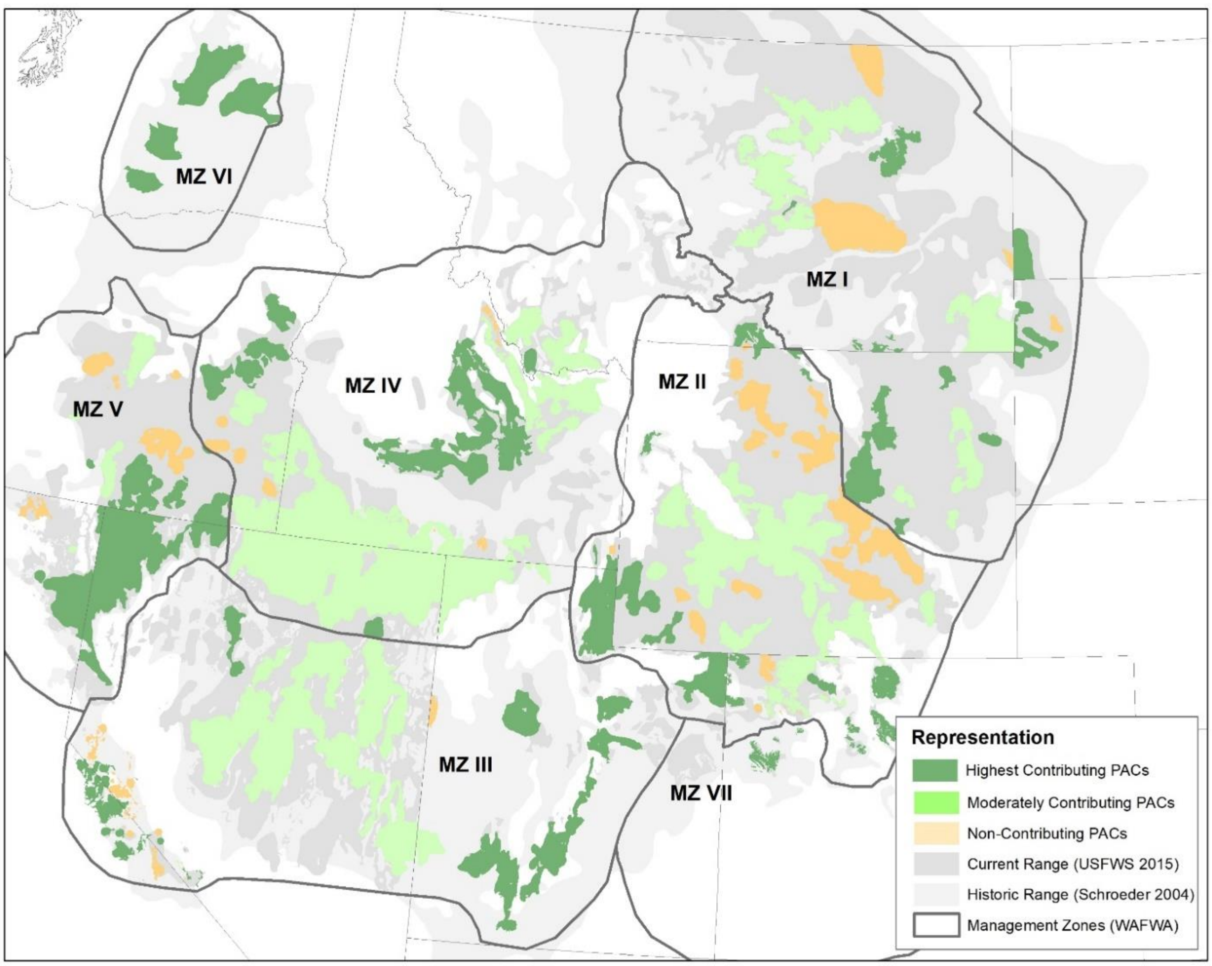

Figure 5. Results of the representation analysis. The highest contributing PACs for representation are shown in dark green while the light green PACs also encompass some diminished habitats but are less concentrated than in the dark green areas. PACs in beige do not contain any of the target habitats for representation.

Representation				
MZ	Number of PACs			
	High	Moderate	Non-contributing	Total
I	13	8	4	25
II	23	11	72	106
III	33	3	38	74
IV	11	9	35	55
V	6	4	9	19
VI	4	0	0	4
VII	18	0	0	18
Total	**108**	**35**	**158**	**301**

Table 6. Summary of Representation analysis by Management Zone.

Resilience

Resistance and resilience to wildfire varies across both the historical range and within the priority area network. Historically, fire regimes in the sagebrush landscapes ranged from 20-25 years in wetter regions where more fuel is available to 60-100 years in arid sage-steppe habitats of southern Idaho. In particularly dry areas such as Nevada, fire did not have a strong influence on the landscape (Welch 2005). Prior to the mid-19th century introduction of cheatgrass, it can be assumed that post fire recovery was a natural process that resulted in the recolonization of burn areas by native species.

Changes across the sagebrush landscape in the early 1900's, particularly the rapid spread of cheatgrass, altered the natural resistance and resilience to wildfire of sage-grouse habitat. As shown in Figure 6, the warm and dry soil regimes of southern Idaho and northern Nevada which historically contributed to the regions' natural resistance to wildfire now facilitate the spread of cheatgrass resulting in an increase in the frequency and size of wildfires.

The effect of cheatgrass on resistance and resilience to wildfire is evident in Figure 7 where many of the low resistance landscapes in MZ IV have burned multiple times since 1984. The other western MZs also have areas with low resistance and multiple fires while the eastern plains have experienced considerably fewer wildfires. Eleven small priority areas have been burned on over 90% of their habitat. Among the larger PACs (in excess of 250,000 ha) the Snake River PAC at the center of MZ IV has burned across 40% of its extent while nearly 30% of the large PAC spanning southern Idaho and northern Nevada has burned. In contrast, the priority areas in MZs I and II where there is a moderate to high resistance to cheatgrass have burned across less than 5% of their total area since 1984.

The burned areas in Figure 7 represent the outer perimeter of the wildfire. Within the perimeter there is typically a varied pattern of burn intensities driven by weather and micro-habitats. Topography contributes to this variability with more diverse terrain resulting in a patchier burn. As shown in Figure 3, MZ I (Great Plains) is fairly uniform topographically while MZs III and IV (Central and Southern Basin and Range) encompass more rugged landscapes resulting in a patchwork of varying burn intensities and potentially leaving unburned areas within the perimeter.

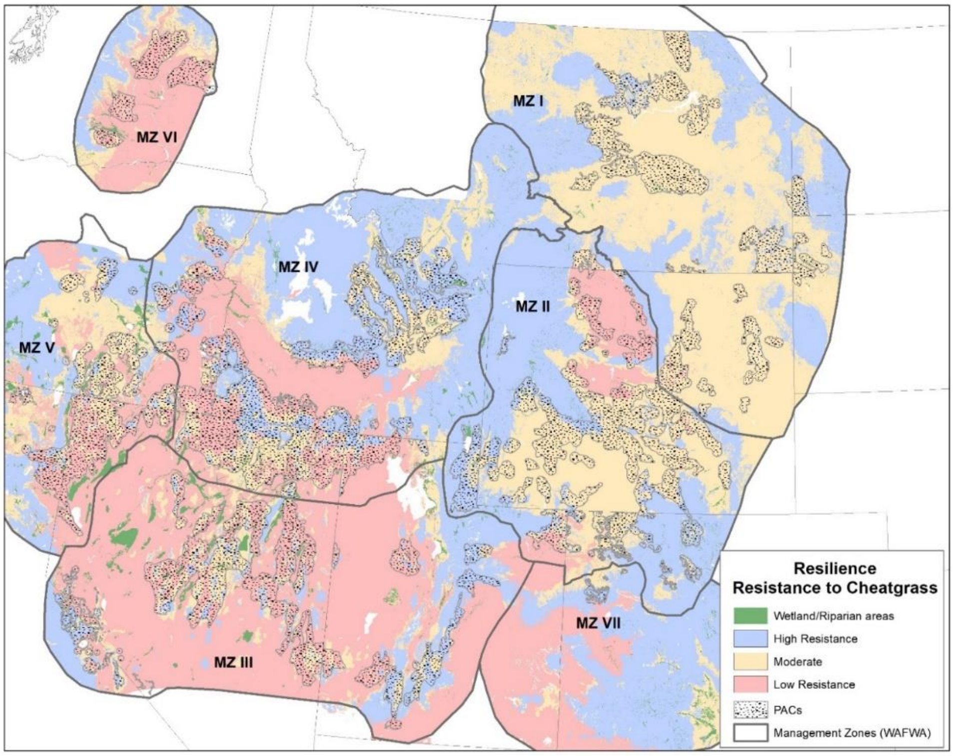

Figure 6. Resistance to cheatgrass invasion based on soil regimes with the warm/dry regimes prevalent in MZs III and IV being more vulnerable than the cool/moist regimes found further to the north and east (Chambers et al. 2017).

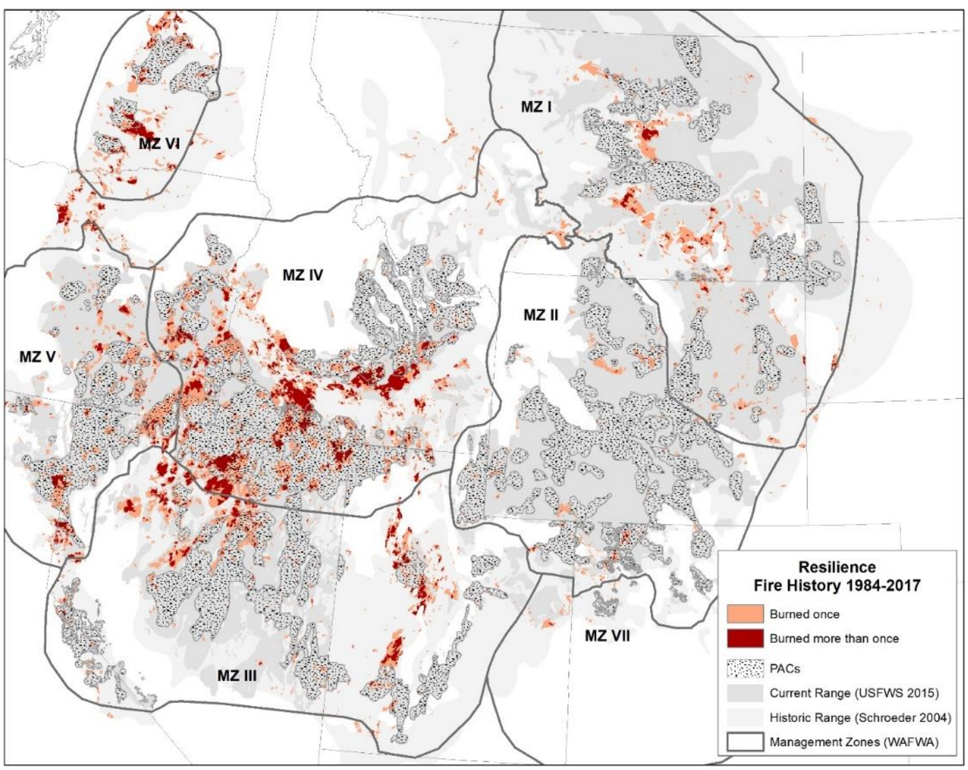

Figure 7. Wildfire history across the historical range from 1984-2017. Fires have been far more prevalent in the central regions, particularly in MZ IV and the northeastern portion of MZ III while they are infrequent in the eastern MZs.

Figure 8 shows the combined results of the three landscape characteristics contributing to wildfire risk (i.e. cheatgrass resistance, recent fire history, and topography). The juxtaposition of these three factors can help to mitigate some of the inherent risk. Areas with low cheatgrass resistance such as the Great Basin in MZs III, IV, and V may experience a more diverse mosaic of burn intensities if there is a high degree of topographic diversity than a similar site within a uniform landscape. Similarly, areas such as the Great Plains region in MZ I that are moderately resistant to cheatgrass but have little topographic diversity have the potential for wildfires to spread rapidly under hot and dry conditions. It should be noted that this analysis does not take into account the effects of land conversion to agriculture and urban development.

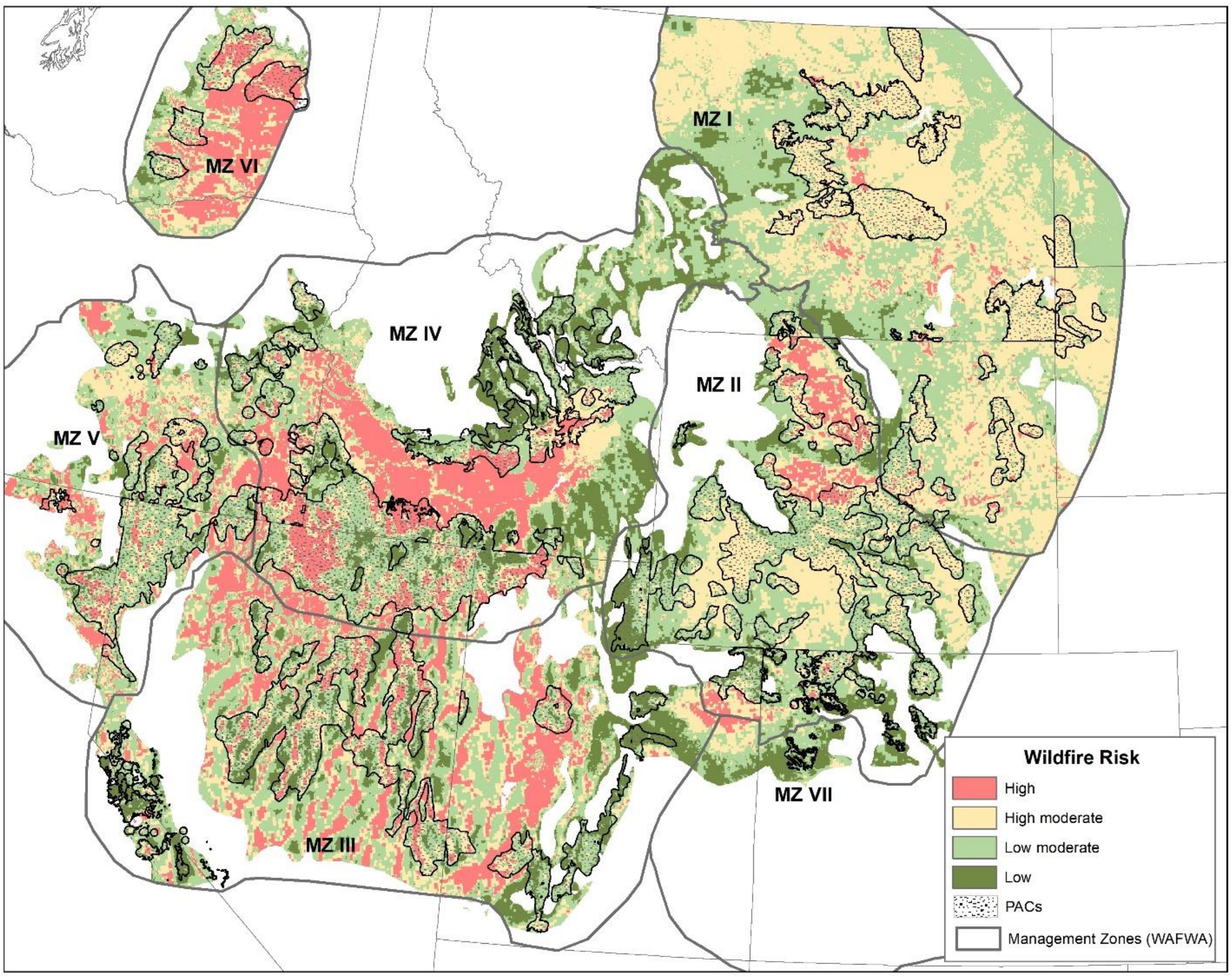

Figure 8. Results of wildfire risk analysis based on resistance to cheatgrass, topographic diversity, and recent fire history.

Natural recovery potential based on the size and connectivity of priority areas further refines the wildfire resilience analysis. The PACs shown in blue in Figure 9 have the highest resilience while those in red have the least. Many of the large PACs classified as resilient contain areas within them that are highly vulnerable to wildfire due to the presence of cheatgrass. However, these PACs also encompass diverse terrain and habitats that can mitigate wildfire effects at the landscape scale and facilitate natural recovery from unburned patches within the wildfire perimeter.

Pathways within the large PACs facilitate the movement of wildlife in response to disturbance events. Therefore, when considered as a single contiguous unit, they are classified as resilient. In contrast, the small isolated patches in fire-prone landscapes are more likely to burn in their entirety and will be more difficult to restore due to a lack of seed sources. Access to suitable habitat as wildfire refugia is also more difficult for resident populations in these highly fragmented landscapes.

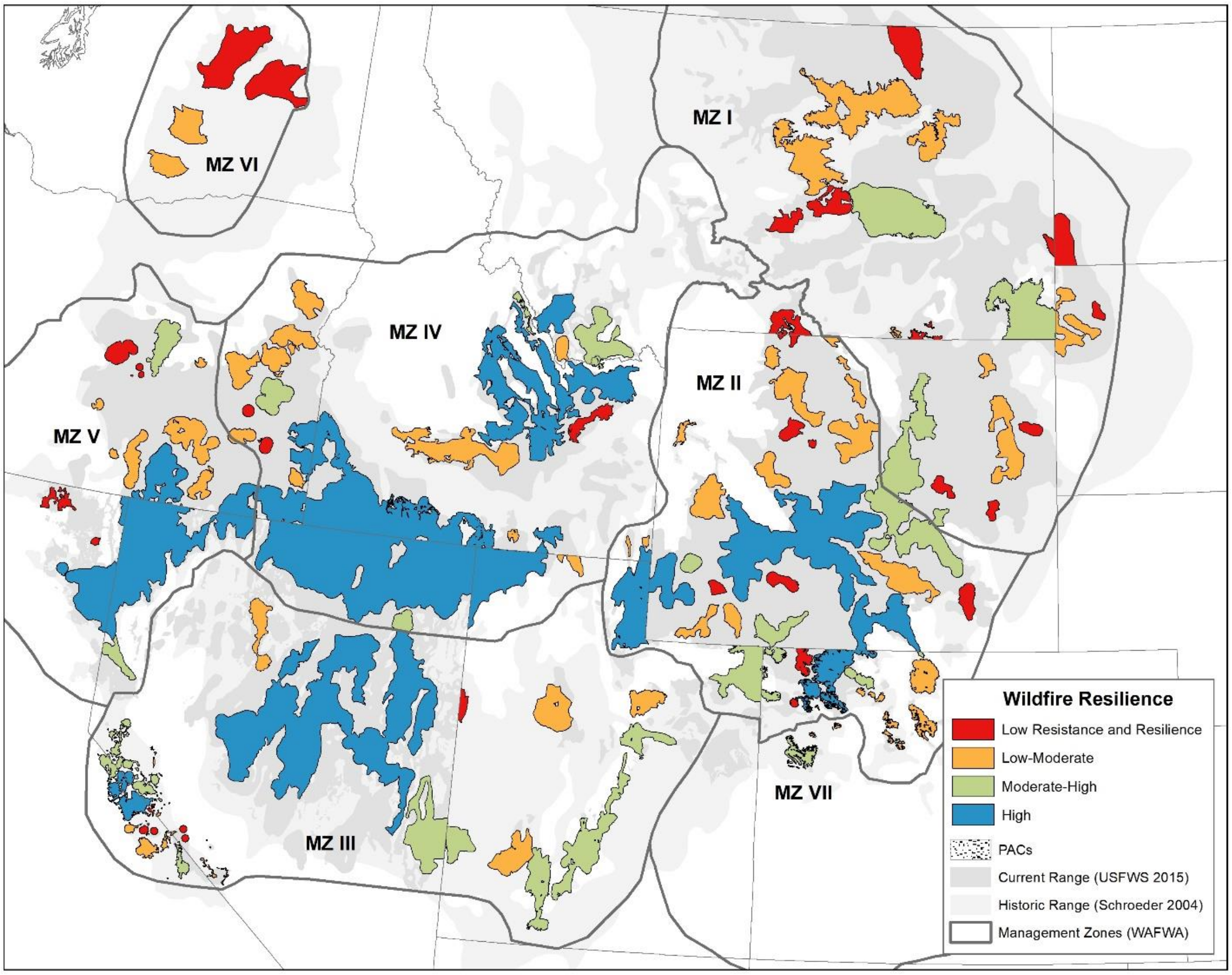

Figure 9. Results of resilience analysis. PACs shown in red have low resistance to wildfire and natural recovery is limited due to small patch size and isolation. PACs in blue have higher resistance and better potential for natural recovery.

Table 7 provides a summary of the PACs by resilience classification. Management zones I and VI are particularly vulnerable to wildfire with a number of priority areas in the low or low to moderate category. Although MZ I is moderately resistant to cheatgrass, the flat terrain facilitates the spread of wildfire and the isolated nature of many of the priority areas may constrain natural recovery. The 34 priority areas classified with a high resilience range in size from 12 to 5.3 million hectares with only 10 over 60,000 hectares, all located in MZs II, III, IV, and V.

Range-wide, these results overstate resilience since many of the large resilient PACs will experience wildfire over portions of their extent while the small priority areas classified as resilient due to local landscape conditions are vulnerable to complete loss should climatic conditions lead to a wildfire. Of the

77 PACs classified in the moderate to high resilience category, only 18 are over 60,000 hectares. Many of the small PACs are found in high elevation clusters in northwestern Colorado (MZ II) and along the Nevada-California border (MZ III) where abiotic factors have limited the spread of cheatgrass and the clustering of priority areas helps to mitigate the isolating effects of the small patch sizes.

Wildfire Resilience					
MZ	Number of PACs				
	High	Mod-High	Mod-Low	Low	Total
I	0	4	9	12	25
II	21	27	40	18	106
III	6	19	28	21	74
IV	5	13	22	15	55
V	1	3	9	6	19
VI	0	0	2	2	4
VII	1	11	5	1	18
Total	**34**	**77**	**115**	**75**	**301**

Table 7. Summary of Resilience analysis by Management Zone.

Redundancy

Table 8 provides a tabular summary of the redundancy analysis by management zone and Figure 10 shows the results spatially. Of the 301 PACs, only 62 (20%) meet both the size and breeding density criteria for redundancy and only 10 of these also meet the criteria for wildfire resilience. Range-wide over 56% of the priority areas are both too small and have too low of a breeding density to contribute to redundancy.

Redundancy						
MZ	Number of PACs					
	Redundant and Resilient	Contributes to Redundancy	Less than 600 km2	Low Breeding Density	LT 600 km2 & Low Breeding Density	Total
I	0	12	6	0	7	25
II	3	18	31	0	54	106
III	2	8	5	1	58	74
IV	4	7	11	2	31	55
V	1	5	4	2	7	19
VI	0	1	0	3	0	4
VII	0	1	4	0	13	18
Total	**10**	**52**	**61**	**8**	**170**	**301**

Table 8. Summary of Redundancy analysis by Management Zone.

The lack of resilient PACs in MZ I is offset by 12 well-distributed PACs that satisfy both the size and breeding density criteria for redundancy thus providing an important safety net should some of the PACs be rendered unsuitable due to wildfire. In contrast, MZs VI and VII do not contain any resilient patches and each have only one PAC that meets both the size and breeding density criteria for redundancy. In MZ VI the four PACs are large but only one of them meets the breeding density criteria and, at the 75%

concentration threshold, it just barely meets it. Seventeen of the 18 PACs in MZ VII do not meet the size criteria and 13 fail to meet both the size and breeding density criteria. With so many small PACs vulnerable to loss from a disturbance event, the long-term representation of this entire MZ is dependent on a single PAC with no safety net.

Management zones II, III, IV, and V each support one or more large resilient PAC as well as at least five PACs that meet the redundancy criteria and are fairly well distributed within each management zone. The exception is in the eastern portion of MZ III where the isolated Sheeprock PAC represents the last vestige of sage-grouse habitat within a large expanse of central Utah and does not satisfy the redundancy criteria due to a low breeding density. This PAC is vulnerable to local extirpation and with no other core habitat patches in the region the unique attributes of this portion of the historical range will be lost.

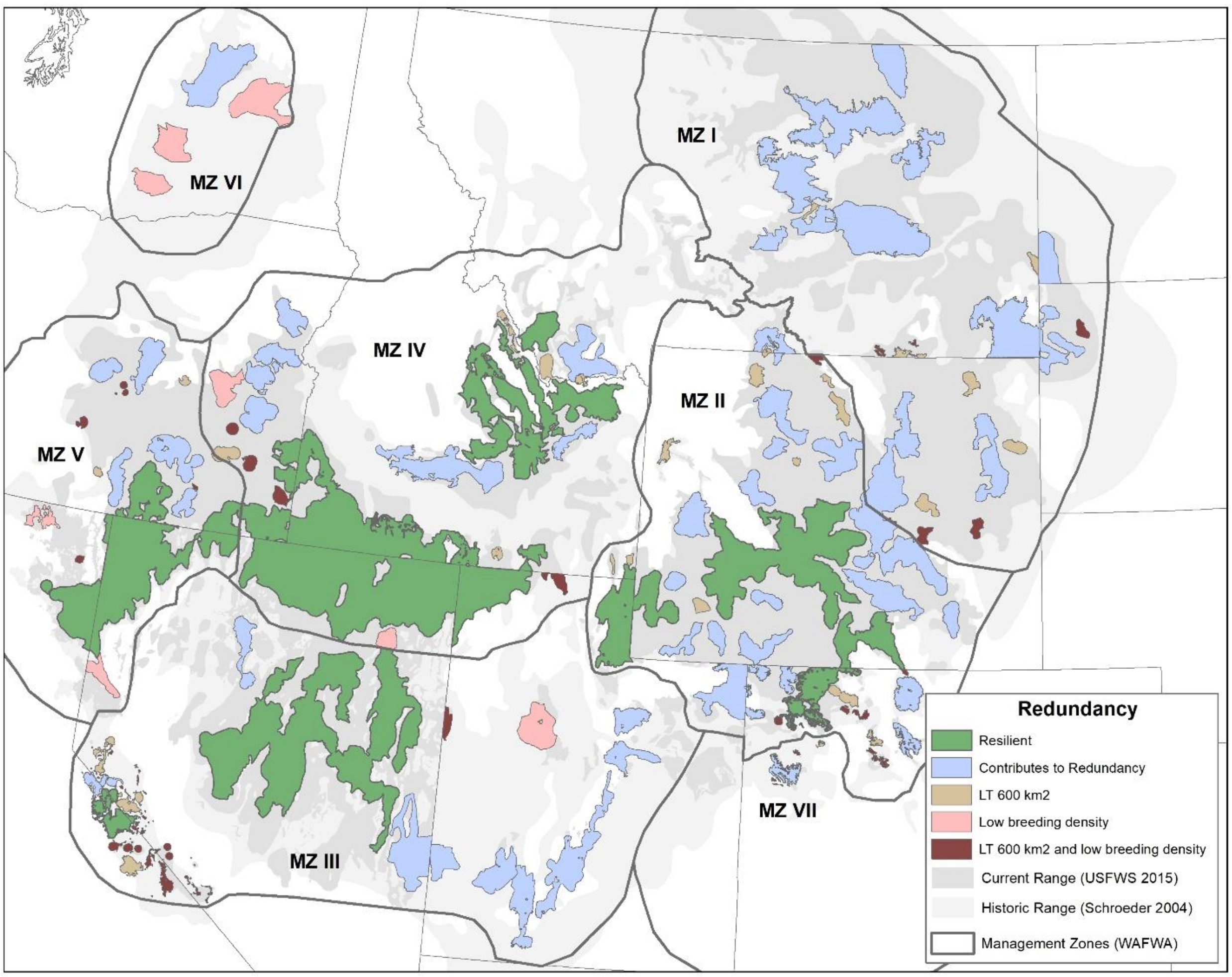

Figure 10. Results of redundancy analysis. Dark green PACs were classified as the most resilient in the previous analysis and satisfy the redundancy criteria for size and breeding density. PACs shown in blue are less resistant and resilient to wildfire but meet the minimum requirements for Redundancy of being at least 600 km2 in size and containing at least one breeding density concentration area of 75% or better.

The separation of MZ VI from the other management zones makes redundancy particularly important to the persistence of the Columbia Basin sage-grouse populations in the range-wide portfolio. However, while all four of the priority areas satisfy the size criteria for redundancy, only one satisfies the criteria for breeding density. A similar situation exists in MZ VII. Although there are more priority areas delineated in this region, they are small and only one satisfies the redundancy criteria leaving the Colorado Plateau highly vulnerable to regional extirpation.

Discussion

The conservation of a landscape-scale species such as the Greater Sage-grouse requires a range-wide perspective that encompasses the full complement of ecosystems and plant communities with which the species evolved. Management of sage-grouse is increasingly focused on the conservation of priority areas thus inextricably linking the efficacy of conserving core habitats to the long-term persistence of sage-grouse. There is a tendency in the delineation of priority areas to focus on centrally located core habitats and population strongholds such that unique habitats and low abundance populations outside of the core areas often fall through the cracks (Smith et al. 2016). Recent studies have emphasized the importance of the landscape outside of the core areas as stopover habitat for long-distance migrants and providing access to seasonal habitats (Newton et al. 2017; Crist et al.2015) as well as pathways for genetic connectivity and dispersal from population centers (Cross et al. 2018; Heinrichs et al 2018; Row et al. 2018), and for the preservation of conservation options as environmental conditions change (Burkhalter et al. 2018).

Taking into account the inherent limitations of a core area approach to the conservation of a landscape species, the 301 priority areas delineated by the Conservation Objectives Team were intended to capture the seasonal and migratory needs of remaining sage-grouse populations across the full extent of their occupied range. A range-wide assessment of these priority areas provides an important perspective on how well local conservation objectives collectively capture the full spectrum of habitat diversity with which sage-grouse evolved. Maintaining this diversity is particularly important in this era of climate change and increasing stochastic events. While landscape changes resulting from disturbance events such as fire and drought can be mapped and quantified, other changes are more obtuse and complex (e.g. shifting plant communities and species' ranges; spread of invasive species; disease) but can also contribute to permanently altered ecosystems. As noted by Figge (2004), portfolio theory underscores the importance of diversifying one's assets when dealing with future risks and uncertainties, regardless of whether those assets are financial investments or habitats.

The 3-R framework provides a systematic approach for evaluating the conservation portfolio of sage-grouse priority areas. The results of this analysis demonstrate that the portfolio for sage-grouse priority habitat is lacking across all three metrics (i.e. representation, resilience, and redundancy) when compared to historical conditions. However, these losses have not occurred uniformly across the species' range. All of the metrics evaluated for representation showed an increased concentration of core habitats within the priority areas while the habitats that were more limited historically have decreased representation. This pattern of loss is particularly evident at the lower elevations and around the range margins. The unique habitats found across the Colorado Plateau, Columbia Basin, and throughout Utah are at risk of being lost to the portfolio completely, furthering the range-wide contraction to the center. Of the 108 PACs that contribute to representation, 56 have low wildfire resilience and fail to meet both the size and breeding density criteria for redundancy.

Resilience has also decreased within the range-wide portfolio when compared to historical conditions. Historically sage-grouse ranged across large patches of high-quality habitat that enabled them to move when disturbances occurred and recolonize an area once the habitat had recovered. Wildfires and drought were part of the historical landscape dynamic but they did not occur at the frequency and intensity we are experiencing today. Some of the largest remaining core habitat patches found across southern Idaho, northern Nevada and southeastern Oregon have shifted from fire-resistant landscapes to fire-prone due to a warm dry climate that is conducive to the spread of cheatgrass. These large PACs encompass diverse terrain with numerous micro habitats that can help to mitigate the spread of a wildfire and provide escape habitat for affected wildlife populations. However, they need to be managed holistically at the landscape scale. If internal pathways and connectivity are severed resulting in multiple disjunct patches of uniform habitat, the wildfire resilience will be lost along with one of the few remaining strongholds for sage-grouse.

In the absence of resiliency, redundancy is important to the preservation of a diverse portfolio. Many of the high priority PACs for representation are scattered in small patches along the range margins. Over 75% of the priority areas are less than 600 km^2. While many of them occur in clusters, should an area become isolated due to a disturbance event or the loss of connectivity between patches, it is unlikely that the small isolated patches will provide for long-term population persistence, resulting in further reductions to the portfolio diversity.

Some may look at the remaining expanse of sage-grouse populations across the West and conclude that the dire predictions of their demise are over-stated. The network of priority areas is fairly well distributed across the occupied range and incorporates some large patches of suitable habitat as well as clusters of small patches. While the PACs may represent a good start to range-wide sage-grouse conservation, they have some significant limitations when viewed from the perspective of the historical conditions that enabled sage-grouse to prosper across the diverse array of western landscapes. Habitat within the priority areas over-emphasizes the more common types to the detriment of the unique habitats. This situation is exacerbated by a lack of resiliency to wildfire for many of the PACs and limited redundancy within several regions around the range margins.

If sage-grouse conservation continues to emphasize core area protection, it needs to ensure that the priority areas encompass as much of the historical sagebrush community diversity as possible, including along the range margins. Recognizing that there are limited opportunities to protect contiguous landscapes at the scale required for range-wide resilience, particularly along the margins, it is important to maintain pathways between priority areas to facilitate seasonal movements and the adaptive capacity to respond to environmental change. Stochastic events are going to continue to increase as the earth continues to warm and management agencies can do very little to change that trajectory. Reducing non-climate stressors within and around priority areas can minimize their vulnerability to disturbances and preserve corridors for movement when a disturbance does occur. Securing a diverse portfolio of well-connected priority areas across the environmental gradients of the historical range is essential if sage-grouse are to retain their evolutionary potential to adapt to changing circumstances and maintain their ecological role as an integral part of the sagebrush landscape. To do anything less will relegate this iconic species to the status of a zoo specimen.

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