Appendix 15. Mid- to Broad-Scale Habitat Conditions and Trends for the Greater Sage-Grouse in Oregon

Abstract

The Greater sage-grouse was determined to be warranted for protection under the Endangered Species Act by the U.S. Fish and Wildlife Service in 2010. As a result, the State of Oregon has undertaken a major effort to update its approach for conserving the species that will ensure that all lands and all threats are addressed. As part of this effort, we assessed mid- to broad-scale baseline conditions and documented methods for assessing habitat conditions over time. This report describes the conditions, trends, and methods for quantifying habitat conditions for the State of Oregon. We relied on relatively straightforward methods adapted from Knick et al. (2013) to examine basic land cover classes such as sagebrush, crop-pasture-hay, and developed lands. We generated summaries for several spatial units to explore differences among these units and provide information to the various working groups to aid in developing an action plan for the sage-grouse. Mean crop-pasture-hay land cover ranged from 0.6% in Priority Areas for Conservation (PACs) to 4.5% among sage-grouse population areas. Mean development ranged from 0.6% in PACs to 1.7% in sage-grouse population areas, and mean sagebrush land cover ranged from 74.1% in close proximity to leks and lek complexes to under 50% in sage-grouse population areas. PACs varied in the amount of the 11 land cover types examined. Big sagebrush shrub, big sagebrush steppe, low sagebrush, and grass habitat types had the widest ranges. Mean crop-pasture-hay and development land cover percentages were quite low and concentrated around towns and cities. Mean percentages of crop-pasture-hay and development among lek occupancy groups (conservation status groups) were also small. Mean percentages of sagebrush land cover decreased as the size of the spatial unit increased, as might be expected by the modifiable areal unit problem. The analysis suggested that there are similarities between the local-scale and regional-scale habitat conditions, but there are also important differences, particularly in relation to historic leks that warrants further study. Change in land cover classes between 2001 and 2010 were generally slight but change in development was statistically significant. Habitat conditions and the metrics used to monitor them also appear to be spatially dependent and therefore care must be exercised when applying results determined at one spatial scale to another.

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Introduction

The greater sage-grouse (*Centrocersus urophasianus*) has seen its population decline (Connelly et al. 2011) and its habitat shrink to approximately half of its pre-European settlement range (Miller et al. 2011). As a result, the species is of conservation concern and was determined to be warranted for protection under the Endangered Species Act (ESA) in 2010 (USFWS 2010). With a final decision due in September 2015, states within the range of the sage-grouse have been developing plans to conserve the species and remove its candidate status. Likewise, the State of Oregon has been diligently preparing information and a plan for conserving and managing sage-grouse. As part of this statewide, multiple stakeholder effort, the Sage-Grouse Conservation (SageCon) Partnership and SageCon's technical team prepared this report.

This report addresses vegetation conditions and levels of development current up to 2010 at a mid-to-broad scale, and builds on work completed by the Oregon Department of Fish and Wildlife (ODFW) in its *Greater Sage-Grouse Conservation Assessment and Strategy for Oregon* (hereafter, 2011 Strategy; ODFW 2011) and work done at the regional scale by other scientists (e.g., Baruch-Mordo et al. 2013; Copeland et al. 2013; Knick et al. 2013). The methods used to complete this report are similar to methods used by ODFW but rely more heavily on more recent work (Knick et al. 2013). Methods developed for this report may be incorporated into a monitoring program for sage-grouse in the State of Oregon.

The objectives of this report were to (i) describe 2010 habitat conditions and the methods used and (ii) describe trends in habitat conditions from 2001 to 2010 and the methods used to determine those trends.

Background

Determination of the baseline habitat conditions was a first step in understanding how to manage sage-grouse habitat in the future. The ODFW 2011 Strategy included an assessment of the habitat baseline conditions for 2005, using data from the *Changes in Sage-Grouse Habitat* (National Land Cover Dataset and SAGESTICH) and fire datasets prepared by the Bureau of Land Management (BLM); all data were acquired between 2004 and 2009. The report indicated that in 2005 there were 3.7 million hectares (ha) (9.2 million acres [ac]) of high-viability habitat in Oregon and that there have been dramatic losses in sagebrush habitat since the 1800s. Since 2005, a number of developments have necessitated a revised baseline conditions assessment that builds on the 2011 Strategy.

The rationale for this report and an alternative habitat baseline is as follows:

1. This report incorporates information provided by recent reports such as the multiagency Conservation Objectives Team (COT) Report (USFWS 2013).

2. The analyses reported here used datasets that were designed for change analysis. The 2011 Strategy relied on datasets available at the time, but they were not designed for change analysis, thus making comparisons between the 2011 Strategy assessments and subsequent assessments challenging. In particular, it is challenging to distinguish between differences that are due to the

different data sources and those that reflect actual landscape change. Change analysis is powerful because it provides information that can be referenced by the USFWS as they make their determination, due in September 2015. The USFWS “warranted but precluded” decision was finalized in 2010. Having information that tracks changes in conditions that are directly comparable simplifies some aspects of the USFWS analysis in 2015.

3. A USFWS decision to list the sage-grouse may have enormous repercussions for the economy of southeast Oregon; therefore, the Governor's office requested that a broader forum be convened to address the wide-ranging impacts of a listing. This analysis was developed to aid in the decision making associated with that process, and, therefore, information about the analysis has been shared on an ongoing basis to increase the transparency of the analytical process.

4. This report incorporates additional stakeholder perspectives and newly available data to facilitate an "all lands, all threats" approach designed to be incorporated into a statewide sage-grouse conservation program.

5. Methods and information were needed for the decision-making process being used to develop a conservation and management framework to be presented to the USFWS in preparation for the 2015 listing decision. To meet this need, we tailored the units of analysis and reporting to facilitate that process. This analysis has helped to inform numerous efforts related to the development of *The Oregon Sage-Grouse Action Plan* (hereafter “Action Plan”) (2015).

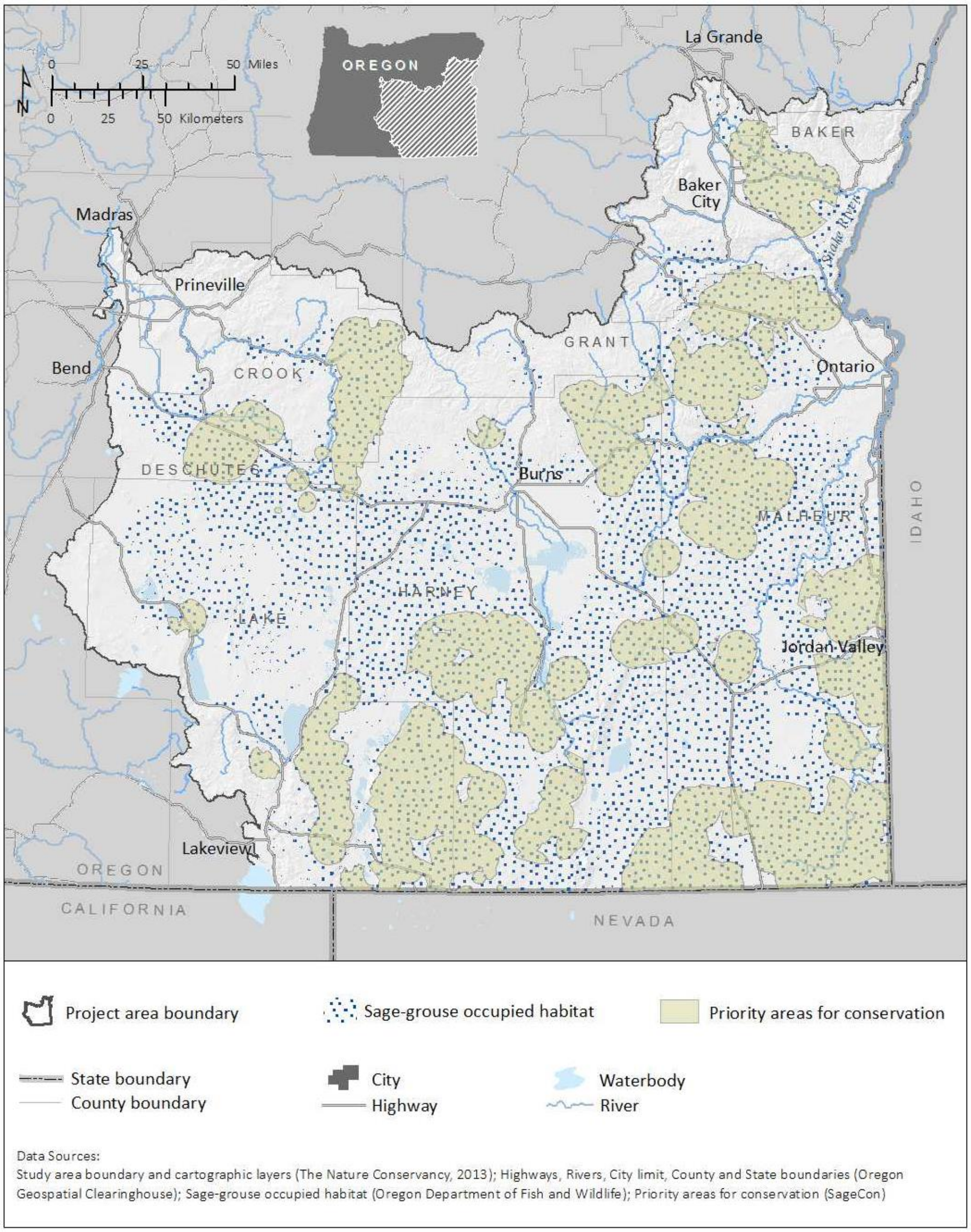
Methods and Data

Project Area

The project area is approximately 23.5 million acres (9.5 million ha) in central and eastern Oregon (Figure 1) and was developed using watershed boundaries (fifth-code hydrologic unit [HUC5]) (U.S. Department of Agriculture-Natural Resources Conservation Service et al. 2011). The spatial extent includes most of the range of the sage-grouse in Oregon, with the exception of the Klamath sage-grouse population in south-central Oregon. Sagebrush steppe habitats are the most abundant habitat types in the project area and make up about 55% of the existing vegetation types. Wyoming big sagebrush (*Artemesia tridentata* Nutt. subsp. *wyomingensis* Beetle and Young) and basin big sagebrush *(Artemisia tridentata* Nutt. subsp. *tridentata*) dominate plant communities at low elevations with relatively warm and dry conditions, and mountain big sagebrush (*A. tridentata* Nutt. subsp. v*aseyana*) plant communities dominate at high elevations with relatively cool and moist conditions. Western juniper (*Juniperus occidentalis* Hook) and other conifer species occur in about 16% of the total project area, primarily in mid-to-high elevations with adequate moisture availability.

Invasion by exotic annual grasses, such as cheatgrass (*Bromus tectorum* L.), medusahead (*Taeniatherum caput-medusae* (L.) Nevski) and others, is a major threat to sage-grouse habitat. These species invade via multiple mechanisms, including higher seeding capacity, earlier germination, and greater winter root growth than most native grasses, enabling earlier and faster use of soil moisture (Knapp 1996). Cheatgrass and other exotic grasses impact wildfire regimes due to the abundant and continuous fine fuels they provide (Knapp 1996). Expansion of western juniper is also a major threat to sage-grouse habitat in Oregon (Boyd et al. 2014). Dramatic alterations in wildfire regimes are tied to shifts in both the composition of drier vegetation communities, such as Wyoming big sagebrush, and in moister communities, where western juniper is expanding (Davies et al. 2011).

Figure 1. Project area and sage-grouse habitat.



Data

To estimate habitat conditions at the broad scale, we used land cover classes in the LANDFIRE Existing Vegetation Type 1.2.0 Refresh data product (LF 2010 [www.landfire.gov]), and to assess trends since 2001, we used the LANDFIRE Existing Vegetation Type 1.0.5 Refresh data product (LF 2001 [www.landfire.gov]). Land cover classes represent vegetation and other physical features, including asphalt and water, on Earth's surface. The Existing Vegetation Type (EVT) data products primarily represent complexes of vegetation communities named or classified according to the Ecological Systems classification (Comer et al. 2003), supplemented with units derived from the National Land Cover Dataset, National Vegetation Classification Standard Alliances, and LANDFIRE specific types. The EVT data products were developed using decision tree models to classify field data, Landsat imagery, elevation, and biophysical gradient data (combinations of climate, physiography, and soils; Keane et al. 2002). The list of LANDFIRE classes included was extensive (Appendix 2). EVT Refresh datasets are rasters with 30-m spatial resolution and were developed to support land cover change analysis. The EVT Refresh layers were also used in the development of other LANDFIRE products. Disturbance classes in the categories of fire, treatments, and exotics were included in the EVT Refresh datasets. The disturbance data were contributed by users to the LANDFIRE program as polygon datasets. The disturbance data was input to the LANDFIRE Events Database and used to refine the landscape conditions derived from modeling (http://www.landfire.gov/about.php). Fire disturbances and management actions such as chemical treatments resulted in shifts from shrubland types to herbaceous or exotic species types, depending on the location and treatments. In lowlands, shrublands were replaced by introduced grasses (exotic grasses) following disturbance (LANDFIRE 2011).

We grouped EVT Refresh classes using the same crosswalk as Knick et al. (2013), which we obtained directly from the source. The groups were used to convert the EVT Refresh datasets to single-theme, binary datasets representing land cover types or *landscape attributes* of interest, using Table 1 (also see Appendix 2).

Table 1. Land cover types of interest. These were developed using a crosswalk by Knick et al. (2013). Member classes for each aggregated landscape attribute are listed in Appendix 2.

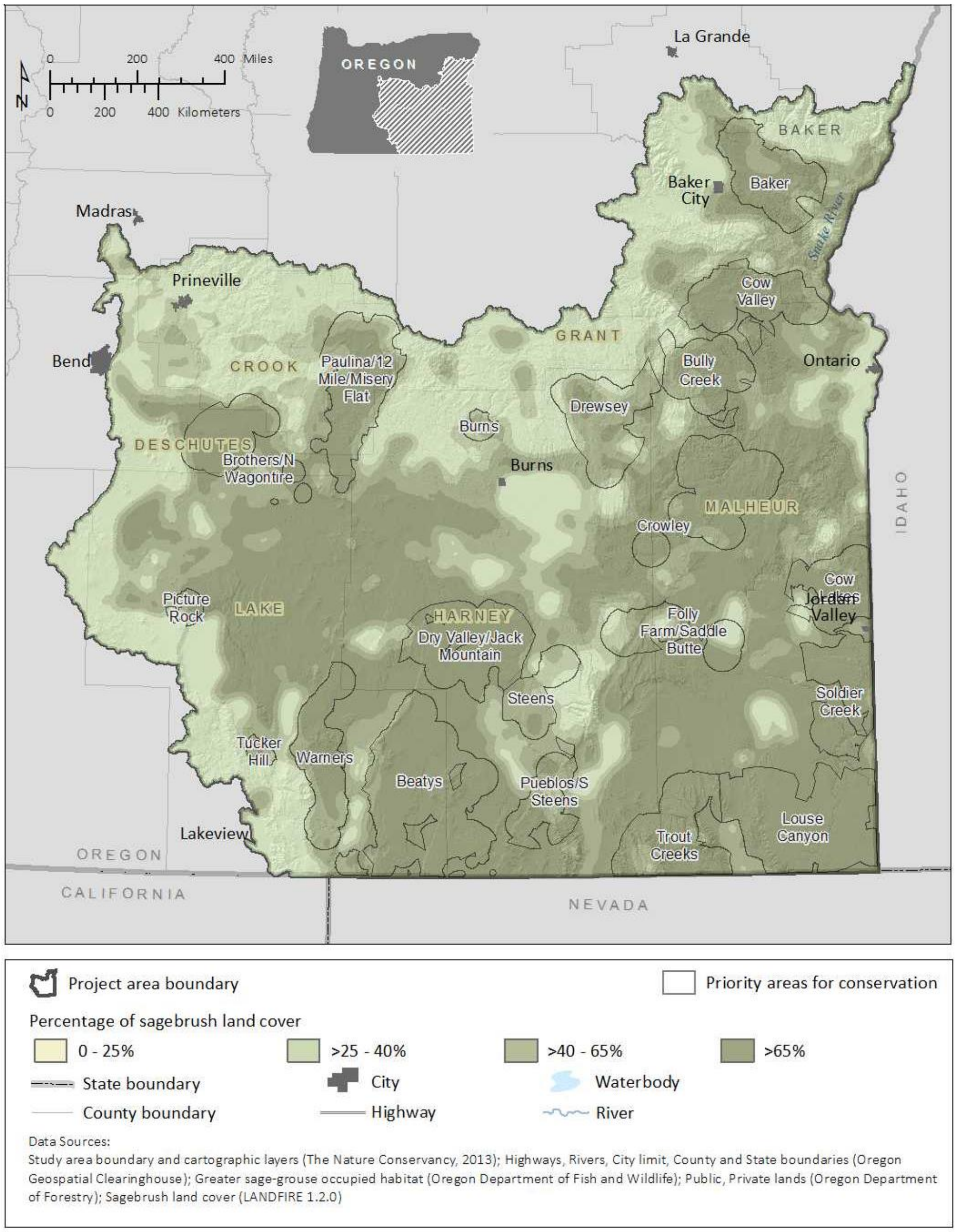
Landscape attribute	Description
CROPPASHAY	Agricultural land use types, including pasture and hay fields and irrigated agriculture.
DEVELOP	Land use types that are primarily human, built environments, including residential and urban land uses.
SAGE	All sagebrush types were aggregated into this class.
BIG_SAGE_SHRUB	This is a single class: "Inter-mountain basins big sagebrush shrubland."
BIG_SAGE_STEPPE	This is a single class: "Inter-mountain basins big sagebrush steppe."
LOW_SAGE	Low sagebrush and scabland shrubs types are included.
MOUNTAIN_SAGE	All mountain big sagebrush types are included.
CONIFER	This includes all non-juniper conifer types such as ponderosa pine-dominated land covers.
JUNIPER	All western juniper types are included in this class in Oregon.
GRASS	All grassland land cover types.
RIPARIAN	All riparian types are included.

Analysis of Habitat Conditions

Habitat conditions were determined for 2001 and 2010 by calculating percentage cover of each habitat type in a GIS for four primary spatial units: the boundaries of the project area, population areas, Oregon Priority Areas for Conservation (PACs), and areas within 5 km of lek locations. In addition, two management units (Bureau of Land Management [BLM] districts and ODFW Sage-Grouse Action Areas [Action Areas]) were also used in this analysis.

Distinct sage-grouse breeding populations delineated and grouped by North American floristic regions (Connelly et al. 2004; pp. 6-1 to 6-77) were modified from Schroeder et al. (2004) to be continuous and cover the entire project area. PACs were developed with ODFW by grouping polygons of core habitat based on proximity and size criteria. Core habitat was mapped using a lek density model (ODFW 2011) and served as the boundary for PACs in Oregon for recent assessments completed by federal agencies (USFWS 2013). PACs were assigned to ODFW management units (Action Areas) and named according to the Action Area in which each PAC was located. We obtained lek location and occupancy data from ODFW in November 2013. The lek locations were buffered, using a 5-km distance to create “lek buffers” that represent lekking grounds and surrounding nesting habitat. Numerous studies have concluded that most nests are situated within 5 km of lek centers (e.g., Holloran and Anderson 2005; Doherty et al. 2010; Coates et al. 2013). Lek buffers overlap in a majority of cases.

Figure 2. Sagebrush land cover in 2010.



Leks were grouped by ODFW into six conservation status categories: occupied, occupied pending, unoccupied, unoccupied pending, historic, and unknown. For some analyses, we aggregated the leks into occupied and unoccupied groups. Occupied leks included leks defined as having one or more males counted in each of seven consecutive years ("occupied" conservation status) and leks that had one or more males at the last visit but had not been regularly monitored over the last seven years ("occupied pending" conservation status). Unoccupied leks were leks with an "unoccupied," "unoccupied pending," or "historic" status category, comprising leks at which no birds were present for eight or more consecutive years in which repeated visits occurred (“unoccupied”); leks at which birds were not present at the last site visit and had not been regularly monitored during the past seven consecutive years (“unoccupied pending”); and leks that have not had males present since at least 1980 (“historic”). Leks with unknown status were not grouped.

ODFW identified lek complexes—groups of lek sites that tend to function as a single unit and are located in close vicinity (≤1 mile), usually with at least one larger lek site (ODFW 2011)— in the lek dataset. Landscape attributes were summarized for lek complexes using all member leks with an occupied or occupied pending status. In addition, the geographic centers, or *centroids*, of the member leks for each lek complex were developed in ArcGIS. We estimated habitat conditions using the landscape attributes for “active” (at least one occupied or occupied pending lek within a complex) and “inactive” (all leks were unoccupied, unoccupied pending, or historic) lek complexes using two methods. The first method used the arithmetic mean as the estimate of habitat conditions in each lek complex; the second method used the inverse distance-to-lek-centroid-weighted average of the attributes of member lek buffers. Only the inverse distance-weighted average was used in the analysis and is presented in this report. The estimates of habitat conditions in the lek complexes were used in place of lek members in subsequent analyses. Lek complexes have not been used extensively by other researchers, and comparisons to other research are limited. However, because lek activity within lek complexes can vary over time, we felt that this approach provides a more realistic representation of sage-grouse habitat associations (but see Walker et al. 2007 for an example in which the lek concept has been used).

The two management-specific spatial units, BLM districts and Action Areas, were also incorporated into our efforts. These units are important to managers in Oregon. BLM is the largest owner and manager of sage-grouse habitat. Boundary data for BLM districts were obtained from the BLM corporate database (http://www.blm.gov/or/gis/data.php). ODFW organized implementation of the 2011 Strategy around the Action Areas; these units were developed with local stakeholder input and include both core and other habitat (mostly low-density). Boundaries for the Action Areas were obtained from ODFW.

Data Analysis

Habitat conditions were estimated for the spatial units and management-specific units of interest (lek buffers, Oregon PACs, ODFW Action Areas, BLM districts, population areas, and the project area), using the 11 landscape attributes described in Table 1. Moran’s I was used to describe spatial autocorrelation among habitat attributes in lek buffers. We also examined change between 2001 and 2010 for three landscape attributes: all-sagebrush habitat, crop-pasture-hay, and development. The Wilcoxon signed rank test was implemented in R (R Core Team 2013) to test for significant change in habitat conditions between the two years. The V statistic was used to assess how different the median land cover proportions were for years 2001 and 2010, with less difference, or change, indicated by V-values close to zero, and more change indicated by larger absolute values. The range of V depends on the number of samples being tested. All GIS data were prepared and analyzed in ArcGIS 10.1. Python scripts were developed to automate summarization by the spatial units of interest.

Results

Spatial and Management Units

Four modified population areas ("population areas") occur in the project area. The population areas ranged in size from 1,551,069 ac to 8,083,788 ac (std. dev = 2,555,030) (Table 2). Four BLM districts ranged in area from 5,771,366 ac to 15,222,301 ac (std. dev. = 3,627,501). Thirty-two ODWF Action Areas ranged in area from 32,208 ac to 939,551 ac (std. dev. = 258,856). There were 20 Oregon PACs that ranged in area from 31,545 ac to 841,398 ac (Table 2); the arrangement of core habitat areas composing individual PACs also varied (Figure 1). Lek buffers had a uniform area of 19,408 ac. One thousand eighty-eight leks were assessed in this analysis. Of these, 514 were members of lek complexes, and 574 were single leks not associated with a lek complex. Of the lek complexes, 156 were active, 28 were inactive, and four were of unknown status.

Table 2. Mean and median area for spatial units assessed.

	5-km Lek Buffers*	Oregon PAC	Action Areas	BLM Districts	Population Areas	Project Area
	n = 1088	n = 20	n = 32	n = 4	n = 4	n = 1
Mean (acres)	19,408.0	328,392.0	344,626.0	5,869,532.0	5,882,039.0	23,526,482.0
Median (acres)	NA	312,868.0	317,850.0	5,550,357.0	6,946,561.0	NA

* Lek buffers are all of equal area, so the mean and median were equal to the area of each lek buffer.

Mean Habitat Conditions

We calculated the habitat conditions as percentages of the total area of individual spatial units (Table 3), then averaged these within the spatial and management units. Mean crop-pasture-hay habitat cover ranged from 0.6% in PACs to 4.5% among population areas. Mean development ranged from 0.6% in PACs to 1.7% in population areas, and mean sagebrush habitat ranged from under 50% in population areas to just over 74% in close proximity to leks and lek complexes.

Crop-pasture-hay occurred across 3.7% and development occurred across 1.5% of the project area. Sagebrush habitat types occurred across more than half of the project area (Figure 2, Table 3). Big sagebrush shrub, big sagebrush steppe, and low sagebrush land covers, in descending order, made up the greatest proportions of sagebrush. Mountain sagebrush occurred across the smallest proportion of the project area. Conifers extended across almost 13% of the project area, and juniper land cover accounted for about 3.6% of the area. Grass habitat types occupied just over 14% of the project area. Riparian land cover types made up the smallest proportion of habitat types in the project area.

The mean sagebrush land cover among population areas was just under 50%, while the mean cover of crop-pasture-hay was 4.5%, and development was 1.7% (Table 3). In descending order, big sagebrush steppe, big sagebrush shrub, and low sagebrush land covers again made up the greatest proportions of sagebrush. The mean amount of mountain sage was just under 3%. Non-juniper conifer types extended across 17.4% of the population areas, and juniper land cover accounted for about 3.1% of the area. Grass habitat types extended across just under 16% of the population areas. Riparian land cover types made up the smallest proportion of habitat types in the population areas.

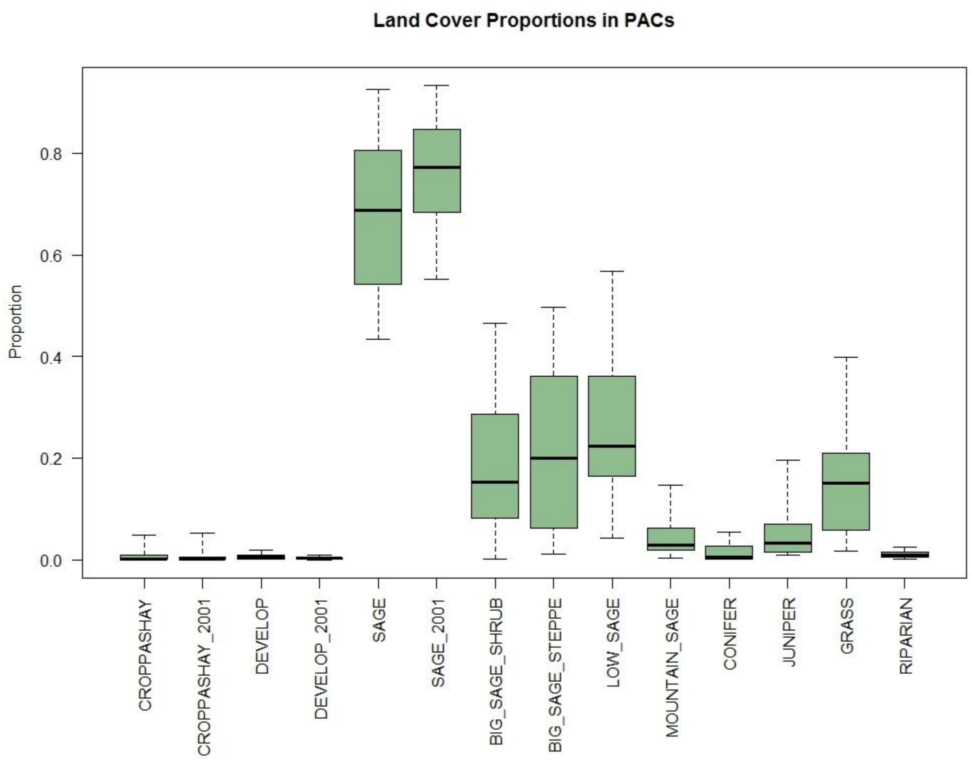
Table 3. Baseline conditions (LF 2010) were calculated as percentages for several spatial units useful for management and monitoring purposes. The high standard deviations suggest that the range of values for a landscape attribute is high and that there is considerable spread around the mean. Unbiased coefficients of variation were used for the assessment units with small sample sizes (CV*).

Landscape Attribute	All Lek/Lek Complexes		Oregon PAC		Action Areas		BLM Districts		Population Areas		Project Area
	n = 760		n = 20		n = 32		n = 4		n = 4		n = 1
	Mean	CV	Mean	CV	Mean	CV	Mean	CV*	Mean	CV*	Percentage
CROPPASHAY	0.80%	3.63	0.60%	1.83	0.90%	1.44	3.40%	0.94	4.50%	1.20	3.70%
DEVELOP	0.60%	2.00	0.60%	1.00	0.90%	1.11	1.60%	0.50	1.70%	0.94	1.50%
SAGE	74.10%	0.28	69.60%	0.22	68.50%	0.21	54.10%	0.28	48.60%	0.72	54.90%
BIG_SAGE_SHRUB	19.30%	1.13	18.30%	0.74	19.80%	0.92	18.90%	0.87	16.20%	1.77	19.90%
BIG_SAGE_STEPPE	23.00%	0.97	21.70%	0.75	25.40%	0.72	18.30%	0.51	18.30%	0.77	18.90%
LOW_SAGE	27.30%	0.88	24.90%	0.55	19.60%	0.69	13.80%	0.46	11.30%	1.03	13.10%
MOUNTAIN_SAGE	4.40%	1.64	4.70%	0.94	3.70%	1.03	3.10%	0.32	2.80%	0.57	3.00%
CONIFER	1.00%	4.30	1.50%	1.20	2.20%	1.41	14.70%	1.35	17.40%	1.54	12.90%
JUNIPER	3.00%	1.57	5.10%	1.00	5.60%	1.04	4.20%	1.33	3.10%	1.48	3.60%
GRASS	13.30%	1.20	15.30%	0.73	15.10%	0.68	12.50%	1.14	15.70%	0.97	14.20%
RIPARIAN	1.00%	1.30	1.10%	0.64	0.80%	0.88	1.20%	0.83	1.50%	1.33	1.20%

Among BLM districts, the mean occurrence of crop-pasture-hay was slightly smaller than in both the project area and population areas at 3.4% (Table 3). Development occurred on average over 1.6% of the districts, and sagebrush habitat types made up 54.1% of the land area on average. As with the project area and population areas, big sagebrush shrub, big sagebrush steppe, and low sage were the most abundant habitat types contributing to the overall sagebrush cover. The mean cover of mountain sagebrush habitats was 3.1%. The mean conifer land cover was almost 15%, and mean juniper land cover was 4.2%. Mean grass land cover was 12.5%, and riparian habitats made up just over 1% of the districts on average.

Average crop-pasture-hay and development were less than 1% in Action Areas (Table 3). Sagebrush habitat types averaged close to 70% across Action Areas. Big sagebrush steppe had a higher average in Action Areas than in the larger spatial units. Big sagebrush shrub and low sagebrush land covers were also somewhat more abundant than in the larger spatial units. Mean conifer land cover was considerably lower than in the broader spatial units (2.2%), and mean juniper land cover was greater than that of other conifers (5.6%). Grass habitat types averaged 15.1% in the Action Areas, and riparian types averaged only 0.8%.

Figure 3. Land cover proportions among all Oregon PACs.The boxplots illustrate the range of data using quartiles. The median is shown by the black line. The range of values is illustrated by the whiskers. Variables with the suffix "_2001" are variables calculated from the 2001 LF 1.0.5 dataset, whereas variables with no suffix are current to 2010. Only crop-pasture-hay, developed, and sagebrush land covers were assessed in the change analysis.

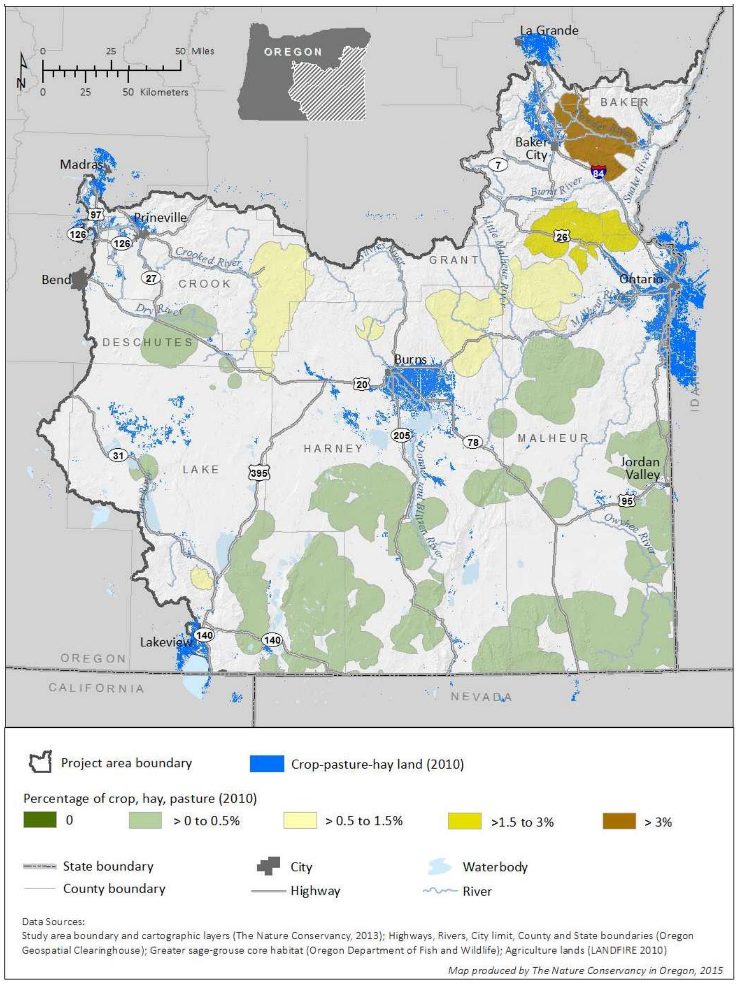


PACs had less crop-pasture-hay and development on average than any other spatial unit (0.6% for each; see Table 3, Figure 3, and Figure 4). Mean sagebrush was high (69.6%), but low sagebrush land cover was the most prevalent sagebrush type among those represented (24.9%) by LANDFIRE EVTs. Conifer types were smaller than all broader spatial units (1.5%), and juniper cover was somewhat lower than the average for Action Areas (5.1%). Mean grass habitat cover was second highest (population areas had the highest grass habitat cover). PACs had the least riparian habitat cover of all the spatial units assessed.

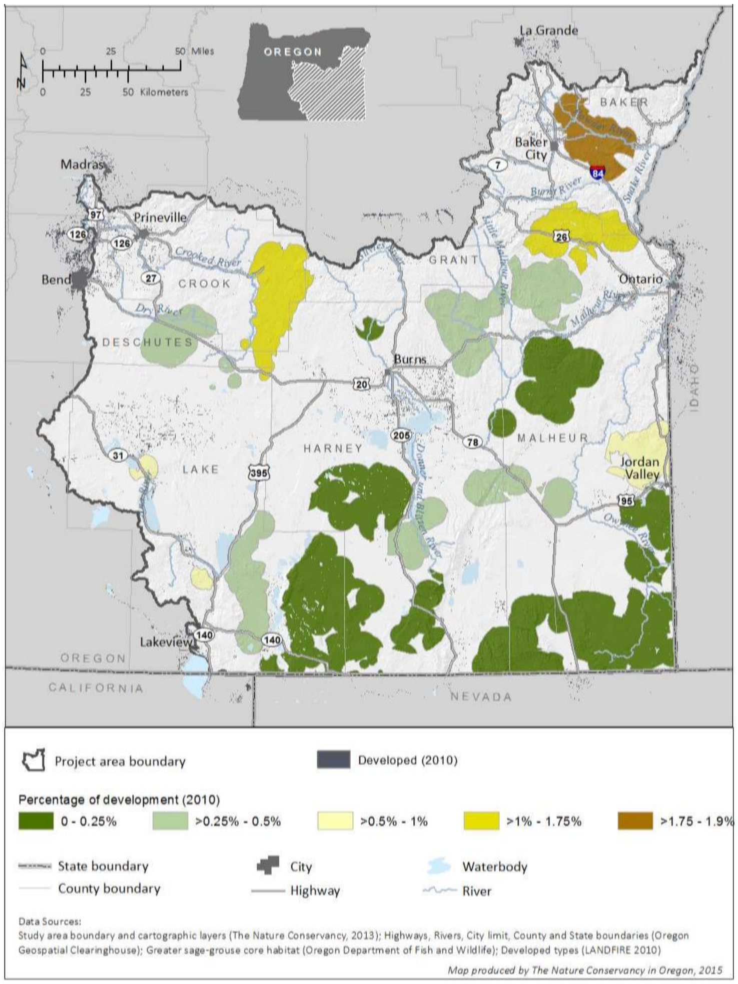
For all lek buffers, mean crop-pasture-hay and development were less than 1% (Table 3, Figure 5). Mean sagebrush habitat cover was higher in lek buffers than in any other spatial unit analyzed. Mean conifer and juniper habitat types were lowest in lek buffers relative to the other spatial units and mean grass habitat cover was the second lowest. Similar to conifer, juniper and grass habitats, riparian habitats were much less prevalent in lek buffers than the other spatial units.

Figure 4. Percentages of (a) crop-pasture-hay and (b) development within PACs.

(a)



(b)



ODFW classified leks as to their occupancy status as previously described, and called this the lek conservation status (Table 4). In the key landscape attribute of sagebrush, estimates of sagebrush land cover were clustered (Moran's I = 0.63, z-score = 48.98, p <<0.000). Land cover proportions of crop-pasture-hay, development and overall sagebrush habitats for 2010 were variable among the different conservation statuses. Crop-pasture-hay cover was highest in close proximity to historic leks (4.1%) and smallest in close proximity to unoccupied leks (0.4%). Developed land cover proportions were highest near historic leks (4.4%) and smallest near occupied pending leks (0.5%). Sagebrush land cover proportions were highest near occupied leks (77.5%) and smallest near historic leks (70.8%). When occupied and occupied pending leks were pooled into the "occupied" class, the group mean sagebrush cover was 74.4%, group mean crop-pasture-hay cover was 0.6%, and group mean development cover was 0.5% (Table 5, Figure 6). When historic, unoccupied, and unoccupied pending leks were pooled into the "unoccupied" class, the group mean sagebrush cover was 75.8%, group mean crop-pasture-hay cover was 3.2%, and group mean development cover was 0.8%. There were only slight differences between the means of the occupied and unoccupied lek groups for the key landscape attributes of sagebrush, crop-pasture-hay, and development. The distributions of the landscape attributes were highly skewed (Figure 6).

Table 4. Leks grouped using the ODFW conservation status field. This field is determined using the most recent 8 years of data on lek occupancy. Statuses with a "pending" modifier indicate that less than 8 consecutive years of data were collected at a lek site, and therefore these statuses have a higher degree of uncertainty than the non-pending classes.

	Occupied n = 118		Occupied Pending n = 503		Historic n = 12		Unoccupied n = 26		Unoccupied Pending n = 380		Unknown n = 49	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CROPPASHAY	0.5%	1.7%	0.6%	2.0%	4.1%	7.5%	0.4%	1.5%	1.0%	3.1%	1.0%	4.6%
CROPPASHAY_2001	0.5%	1.8%	0.6%	2.0%	4.4%	7.7%	0.3%	1.4%	1.0%	3.3%	1.1%	5.0%
DEVELOP	0.6%	1.3%	0.5%	1.1%	1.7%	1.9%	0.7%	1.1%	0.7%	1.7%	0.5%	1.2%
DEVELOP_2001	0.3%	0.5%	0.3%	0.6%	1.1%	1.4%	0.4%	0.6%	0.3%	0.7%	0.3%	0.7%
SAGE	77.5%	20.6%	73.7%	19.4%	70.8%	15.0%	75.2%	29.8%	76.0%	19.9%	74.4%	17.4%
SAGE_2001	81.6%	14.7%	78.1%	15.0%	72.3%	13.2%	87.4%	10.7%	79.2%	17.5%	76.8%	15.7%
BIG_SAGE_SHRUB	13.6%	16.6%	19.7%	22.2%	18.1%	10.2%	10.2%	9.9%	17.9%	19.7%	25.8%	27.1%
BIG_SAGE_STEPPE	22.2%	21.0%	22.0%	21.9%	38.3%	19.8%	20.3%	22.5%	23.9%	22.6%	25.0%	19.8%
LOW_SAGE	37.9%	27.9%	26.8%	22.6%	13.2%	13.3%	41.6%	32.2%	29.4%	25.2%	18.7%	21.1%
MOUNTAIN_SAGE	3.8%	5.5%	5.3%	7.0%	1.1%	1.6%	3.2%	6.3%	4.7%	8.0%	4.9%	9.5%
CONIFER	0.9%	2.9%	0.9%	3.3%	0.1%	0.1%	0.4%	1.0%	1.0%	4.9%	1.6%	5.3%
JUNIPER	4.7%	6.8%	3.0%	4.7%	1.2%	1.4%	2.6%	3.4%	2.8%	4.2%	1.4%	1.9%
GRASS	10.4%	15.7%	13.7%	15.8%	19.2%	15.9%	16.6%	28.0%	10.7%	13.4%	16.1%	15.2%
RIPARIAN	1.0%	1.4%	1.1%	1.4%	1.5%	1.5%	0.5%	1.0%	0.9%	1.2%	1.1%	1.5%

Lek complexes were separated from single leks and grouped into “active” and “inactive” classes by ODFW (Table 6). In the key attributes of crop-pasture-hay, development, and sagebrush, the mean land cover percentages for active lek complexes were 0.6%, 0.6%, and 77.1%, respectively. Mean land cover percentages for inactive lek complexes were 1.2% (crop-pasture-hay), 1.2% (development), and 73.7% (sagebrush). Mean percentages for lek complexes were similar to those of all leks.

Figure 5. Percentage development in lek buffers in 2010. Single leks are indicated by dots; active lek complexes are indicated by triangles. Circles illustrate the number of leks per lek complex.

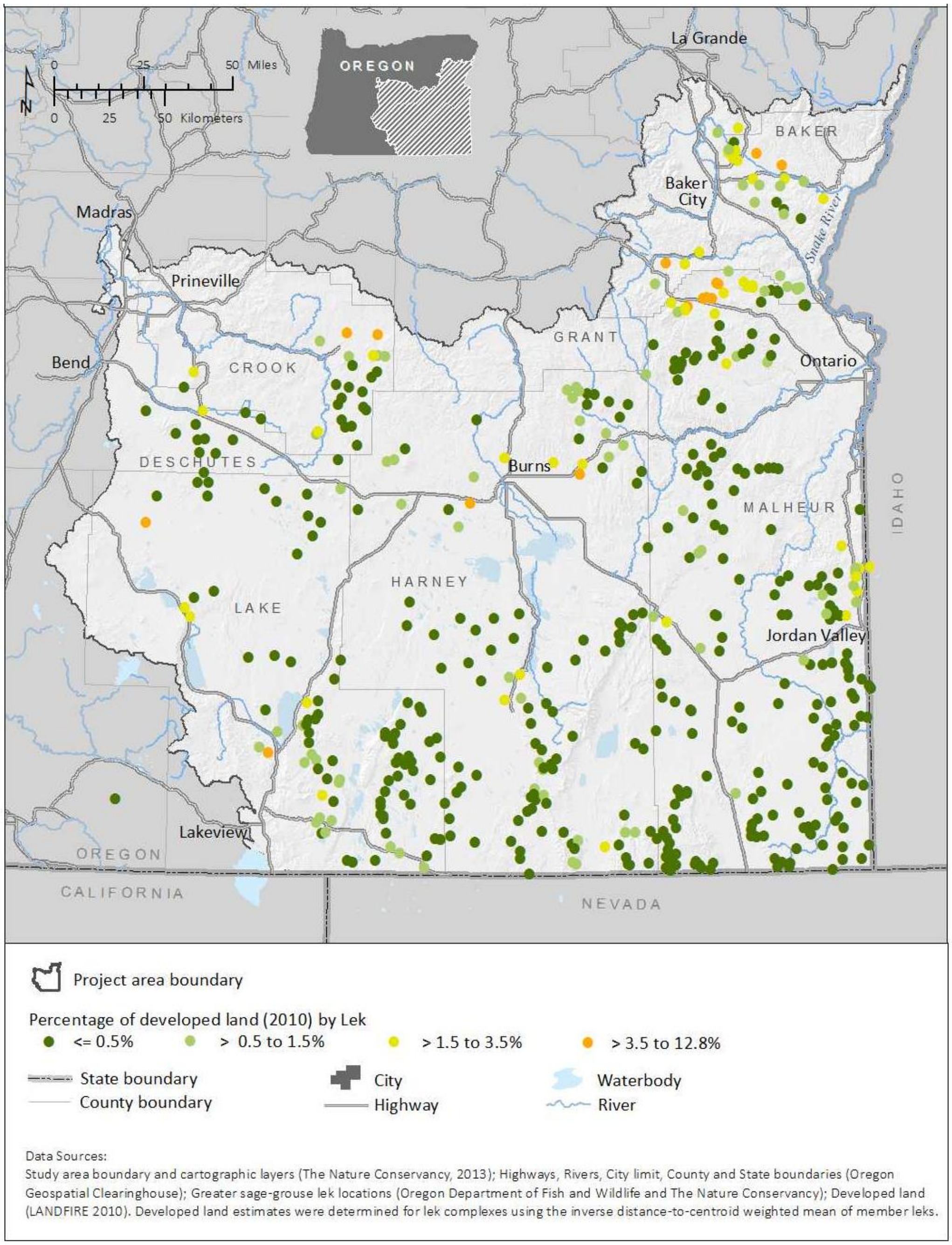


Table 5. Percentage of landscape attributes within lek groupings.

		Sagebrush		Crop-pasture-hay		Development	
Conservation status	**No. of leks**	**Group mean**	**Group SD**	**Group mean**	**Group SD**	**Group mean**	**Group SD**
Occupied Occupied pending	118 503	74.4%	19.7%	0.6%	2.0%	0.5%	1.1%
Historic Unoccupied Unoccupied pending	12 26 380	75.8%	20.5%	1.1%	3.2%	0.8%	1.7%
Unknown	49						
Total	**1088**						

(a)

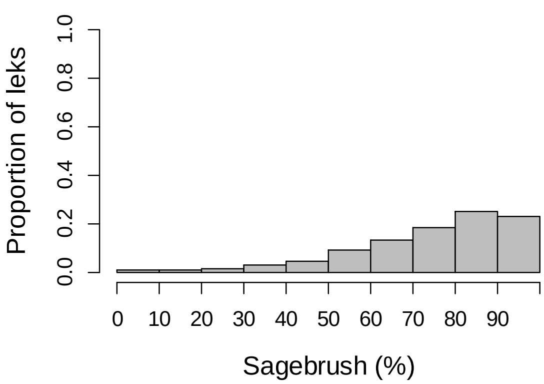
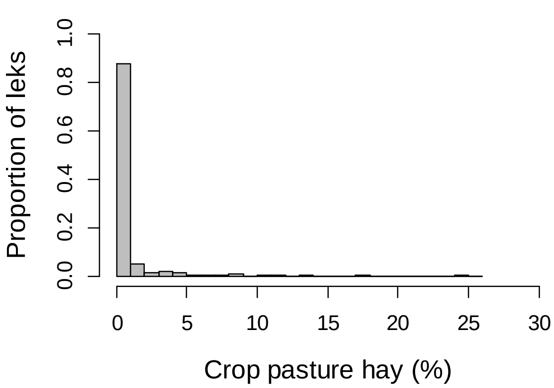
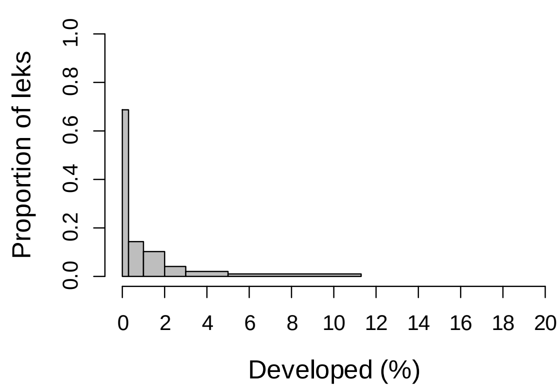


Figure 6. The proportion of occupied and occupied pending leks relative to the percentage of the three landscape attributes. The three attributes are illustrated in three graphs: (a) sagebrush, (b) crop-pasture-hay, and (c) development. The vertical axes represent the proportion of leks falling into each percentage class represented on the horizontal axis. The horizontal axes are not equivalent among the graphs.

(b)



(c)



Past Conditions and Current Trends in Habitat

At the project area level, crop-pasture-hay decreased and development increased between 2001 and 2010 (Table 7). Mean amounts of sagebrush habitat in the project area decreased. Among population areas and BLM districts, we found the same trends for crop-pasture-hay, development, and sagebrush as at the project area. Statistical significance was not tested for these units due to the small sample size.

Among Action Areas, the mean change in sagebrush was slight but significant ($p < 0.001$, $V > 0$; Table 7). Changes in crop-pasture-hay were also small and not significant ($p = 0.6$, $V = 235$). Changes in development were slight but significant ($p < 0.001$, $V > 0$).

Mean amounts of sagebrush habitat have decreased in PACs since 2001 ($p < 0.001$, $V = 210$; Table 7), and appears to be related to habitat changes due to fire (Figure 7). Change due to fire was not controlled for. Change in crop-pasture-hay in PACs was not significant ($p > 0.15$, $V = 82$) and was concentrated in a few areas (Figure 8). Change in development was slight but significant ($p < 0.001$, $V > 0$) and also primarily limited to one PAC (Figure 9).

Among leks, sagebrush decreased by 4.3% ($p < 0.001$, $V = 253{,}180$; Table 7). Mean change in crop-pasture-hay was extremely small and not significant ($p > 0.05$ level, $V = 61{,}033$). Mean change in development was small but significant ($p < 0.001$, $V = 2{,}272$). Changes in landscape attributes associated with member leks in lek complexes were slight but were not tested for significance.

Table 6. Land cover among lek complexes. Lek complex status was defined as "active" if there was at least one occupied or occupied pending lek within the complex, and the complex status was defined as "inactive" if all leks were unoccupied, unoccupied pending, or historic. Lek complex members are leks that are grouped into a lek complex. Single leks are the remaining leks that are not associated with a lek complex.

	Active complexes n = 166		**Inactive complexes** n = 28		**Unknown complexes** n = 4		**All single leks** n = 574	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CROPPASHAY	0.6%	2.2%	1.2%	2.5%	0.7%	1.2%	0.9%	3.1%
CROPPASHAY_2001	0.6%	2.2%	0.9%	2.5%	0.6%	1.1%	0.9%	3.2%
SAGE	77.1%	17.9%	73.7%	23.7%	74.1%	20.0%	73.4%	20.8%
SAGE_2001	80.4%	14.3%	78.7%	18.3%	74.3%	19.8%	77.9%	16.7%
DEVELOP	0.6%	1.4%	1.2%	2.7%	0.4%	0.5%	0.6%	1.1%
DEVELOP_2001	0.2%	0.5%	0.3%	0.8%	0.3%	0.4%	0.3%	0.7%

Table 7. Mean percentages of habitat in 2001, based on LANDFIRE 2001 Refresh data, and change since 2001. Wilcoxon rank sum tests were used to test for significant change between 2001 and 2010 among leks/lek complexes, PACs, and Action Areas. Significant change is indicated in boldface. Rank sum tests were not performed on BLM districts, population areas, or project area because of the small sample sizes (n = 4).

	Leks/Lek Complexes n = 760			Oregon PAC n = 20			Action Areas n = 32		
	Mean	CV	Change since 2001	Mean	CV	Change since 2001	Mean	CV	Change since 2001
CROPPASHAY	0.80%	3.75	0.00%	0.60%	2.00	0.10%	0.80%	1.75	0.00%
DEVELOP	0.30%	2.33	**0.30%**	0.30%	1.00	**0.20%**	0.50%	0.80	**0.40%**
SAGE	78.30%	0.21	**-4.30%**	76.10%	0.16	**-6.50%**	74.60%	0.17	**-6.10%**

	BLM Districts n = 4			Population areas n = 4			Project Area n = 1	
	Mean	CV	Change since 2001	Mean	CV	Change since 2001	Prcnt	Change since 2001
CROPPASHAY	3.50%	0.86	-0.10%	4.70%	1.19	-0.20%	3.70%	-0.10%
DEVELOP	0.90%	0.67	0.70%	1.00%	1.00	0.80%	0.80%	0.70%
SAGE	58.40%	0.27	-4.30%	52.60%	0.71	-4.10%	59.50%	-4.60%

Figure 7. Change in sagebrush habitat types since 2001 in core habitat areas. Fire is depicted to illustrate overlap between core and burned areas.

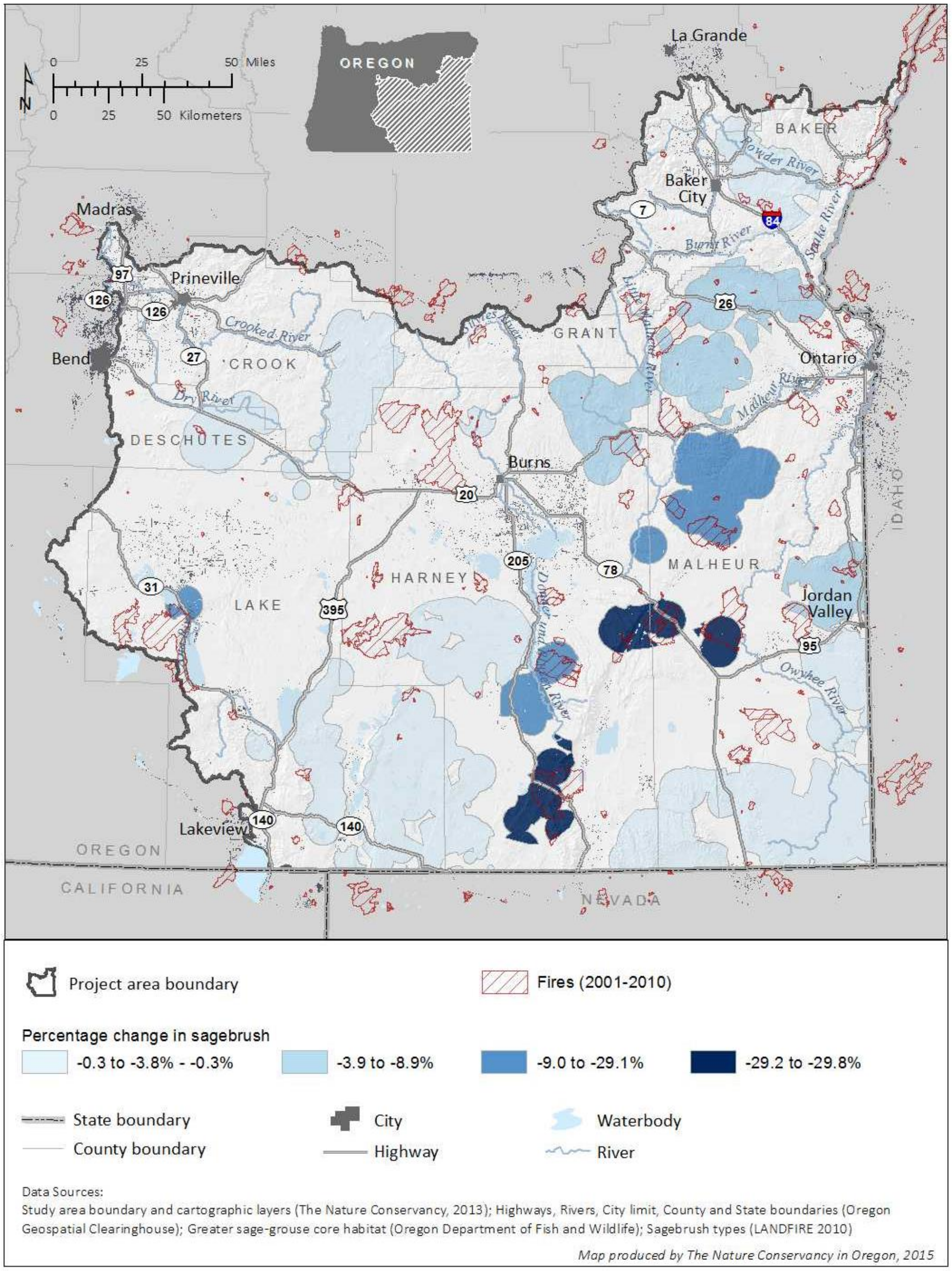


Figure 8. Change in crop-pasture-hay since 2001 in core habitat areas.

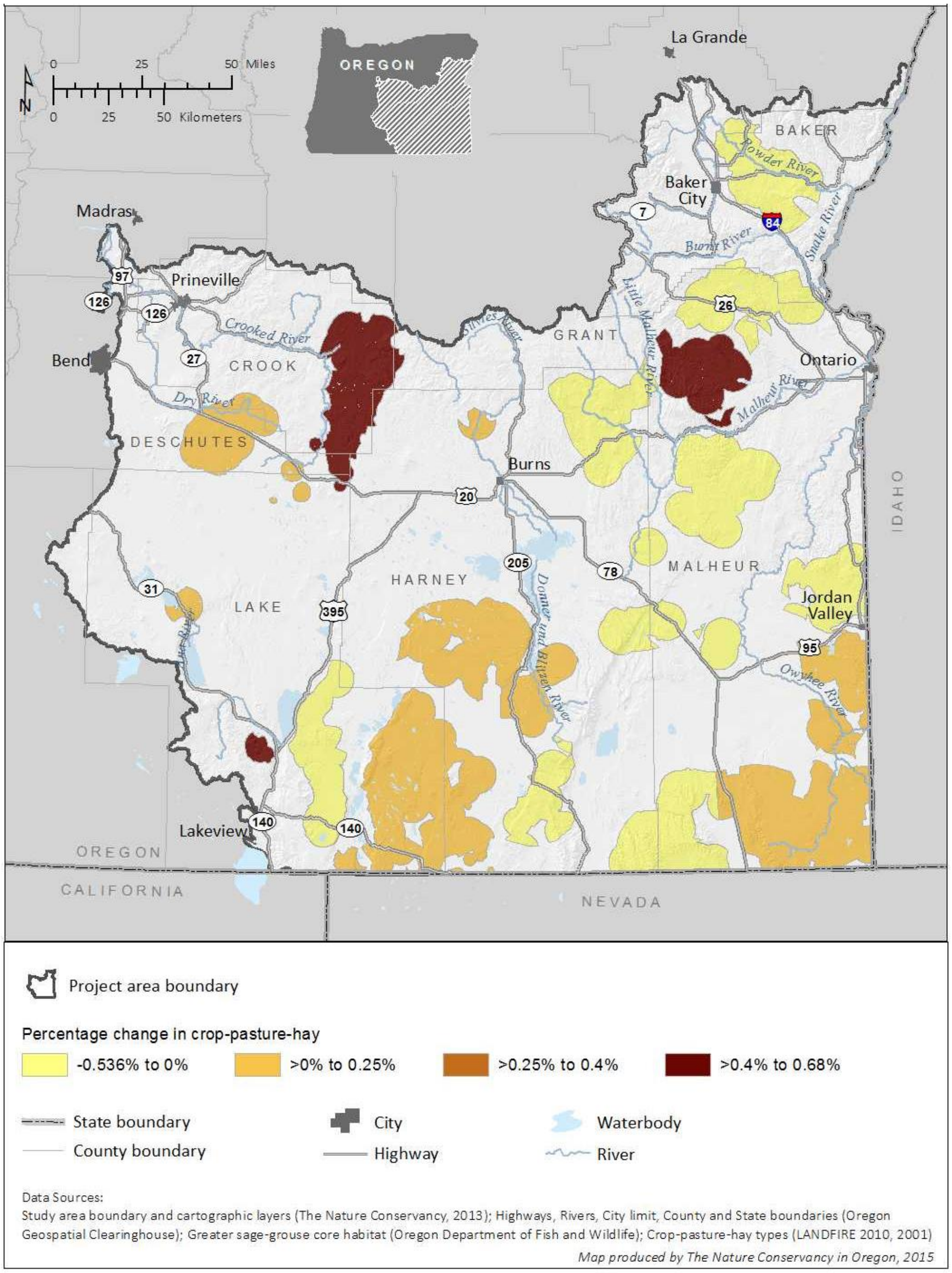
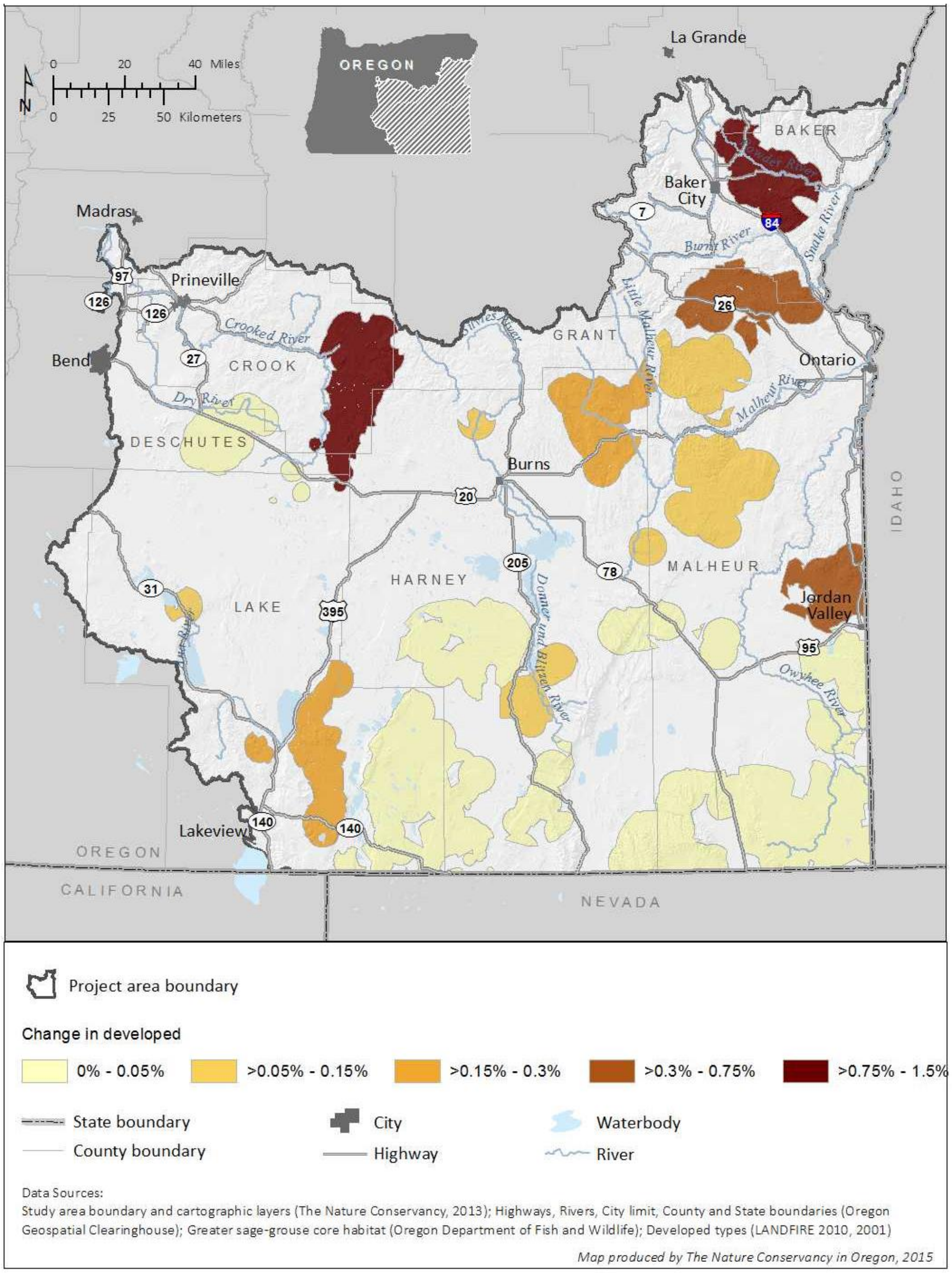


Figure 9. Change in developed land cover since 2001 in core habitat areas.



Discussion

Habitat Conditions

Among the spatial units examined, we observed that there was a relationship between the size of the spatial units analyzed and the amount of the sagebrush, development, and crop-pasture-hay in the units. We expected to see this relationship because the smallest units were determined using knowledge and data about sage-grouse habitat selection in the vicinity of lekking sites, and the larger units were developed for a variety of reasons and uses. More specifically, we observed that mean sagebrush land cover declined as the spatial unit size increased. Individual sagebrush type land covers also declined. These declines were expected because, as the spatial unit extent increased, the biophysical variation (topography, soils, micro-climates, etc.) was also likely to increase. Greater biophysical variation is tied to greater variation and number of land covers encountered. Crop-pasture-hay and development percentages increased as the spatial unit size increased. Because the smallest spatial units (leks/lek complexes and PACs) were defined according to sage-grouse locations and population densities, we expected that the abundance of crop-pasture-hay and development would be less in leks/lek complexes and PACs than it was in the BLM districts, population areas, and the project area. This is because the bird generally avoids disturbance and preferentially selects its habitat away from disturbed habitats.

In BLM districts, sagebrush land cover was considerably lower than those identified by the 2011 Strategy, so we may be underestimating values due to our reliance on EVT Refresh data. Some difference may be owed to the 30-m native resolution of the EVT data versus the 90-m native resolution of the SAGESTICH data used in the ODFW analysis. The larger cell size could contribute to different values relative to our estimates, depending on the spectral and geometric (i.e., shape) characteristics of the features captured in the EVT data.

We expected and found that PACs contained the best conditions for supporting sage-grouse and had high levels of sagebrush land cover, with a mean percentage of >70% for sagebrush habitat. Our results were in agreement with recent investigations that suggest that a biological threshold exists for sage-grouse habitat selection at around 70% habitat land cover (Baruch-Mordo et al. 2013; Knick et al. 2013). Likewise, the conditions associated with occupied leks and lek complexes were similar to those in recent investigations, especially in the key land covers of crop-pasture-hay, development, and sagebrush.

Past Conditions and Habitat Change

We observed decreased sagebrush in all spatial units between 2001 and 2010 but only tested for significance in Action Areas, PACs, and leks/lek complexes due to small sample sizes in the other spatial units. Declines in sagebrush between 2001 and 2010 were statistically significant in the spatial units tested for significance (Action Areas, PACs, and leks/lek complexes). PACs experienced the greatest losses in sagebrush and leks/lek complexes had losses in line with the BLM districts. Population areas experienced the smallest losses, but these were only 0.2% less than those observed at the leks/lek complexes and district levels.

Development increased across all spatial units, with the smallest and second-smallest increases observed in PACs and leks/lek complexes. Increases between 2001 and 2010 were statistically significant for the spatial units tested for significance (Action Areas, PACs, and leks/lek complexes). This result suggests that development has been slowed in the most important habitat areas in comparison to the larger and more diversely used landscape.

We found that the slight increase of development land cover in PACs was significant between 2001 and 2010. This may be because it was concentrated spatially (Figure 5) rather than distributed evenly throughout the project area. We also found that sagebrush significantly decreased. Overlay of fire perimeters from 2001 to 2010 over the PACs identified several large fires that affected several PACs (Figure 7).

We observed that a few PACs contributed most to the overall decrease in sagebrush (Figure 7), and that they are in locations that have been affected by large wildfires in the past 31 years, which we observed by overlaying fire perimeter data from the Monitoring Trends in Burn Severity dataset (http://www.mtbs.gov/). The wildfires have occurred in areas of moderate-to-high risk of exotic grass invasion according to the resistance and resilience concept (Chambers et al. 2014), and exotic annual grasses have been mapped over extensive portions of the wildfire-impacted PACs (SageCon 2015). PACs with decreased sagebrush appear to occur in different areas than where crop-pasture-hay and development increased (Figure 7, Figure 8, Figure 9), suggesting that geographic location or local drivers play an important role in addressing threats to sage-grouse.

Conditions associated with occupied leks/lek complexes suggest that sagebrush has decreased by about 4% since 2001, but is still in the range where probability of lek persistence is high (Knick et al. 2013; Chambers et al. 2014). Wildfire and invasive annual-grass expansion as well as juniper encroachment were likely strong contributors to the observed decrease in sagebrush. Human activities, signified by crop-pasture-hay and development, increased negligibly and slightly, respectively, with the increase in development at about 0.3%. Development increases were observed throughout the planning area, with some clustering (Figure 9).

Changes in crop-pasture-hay have some uncertainty associated with them, as the extent of these can change annually based on weather conditions, crop rotations, economic factors, and other factors. Without further analysis of inter-annual change, it is not clear if the changes (or lack of change in the case of occupied leks) in crop-pasture-hay observed within the spatial units are real trends, are related to inter-annual variation, or are a combination of both.

Historic leks had considerably higher levels of human activities than other leks in Oregon. Crop-pasture-hay levels were considerably lower than the ecological minimums identified by Knick et al. (2013), but development levels were in line with the trends observed by that research. The high levels of sagebrush in the 5 km buffers surrounding historic leks suggest that sagebrush loss may not be the main driver of lek extirpation in Oregon, and further research is needed to understand this implication. Instead, broader-scale processes such as habitat fragmentation, local disturbances, or a combination of changes in habitat may have influenced the occupancy of these leks.

Only minor differences were observed among the occupied pending, unoccupied, and unoccupied pending leks. Additional work is needed to identify the “pending” conservation statuses and to differentiate the conditions leading to unoccupied, historic, and occupied leks. An extension of this additional work is the need to more clearly relate sage-grouse population dynamics to land cover change dynamics in Oregon (but see Knick and Hanser 2011 for an example of a regional analysis).

Limitations

Spatial autocorrelation

A number of limitations were evident in the work presented here. Spatial autocorrelation was apparent in the estimates of habitat conditions in close proximity to leks. Spatial autocorrelation may bias habitat condition estimates, as numerous locations were "double sampled" due to overlap in two or more lek buffers throughout the project area. It may also exist within other spatial units such as the PACs. Additional work is needed to account for this potentially confounding factor.

Issues related to spatial scale and extent

The methods used to complete this analysis were prepared with the intention that they could be used in future assessments of habitat for the State of Oregon while also facilitating decision-making processes. To meet the anticipated need for future monitoring, we used several criteria in our selection of the methods. First and foremost, we felt that it was important that the methods be relatively easy to understand by the collaborators and to replicate by analysts. To this end, the spatial units selected for the assessment were chosen to make sense to the collaborators, land managers, and other decision makers. Other important selection criteria were that data were readily available, consistent, and complete, and could be used to assess change over time. Because the types and characteristics of data products tend to evolve and improve over time, we also wanted methods that could be adapted to the emerging datasets. Finally, we wanted to ensure that comparisons could be made across data resolutions and spatial extents. For example, we wanted to ensure that differences in the estimates of habitat conditions could be standardized to allow relationships to be calculated between fine- and coarse-resolution datasets and across different management units. It was assumed that these conditions were true for the analyses presented here; however, the variation in size within and among the spatial units assessed was substantial (Table 2). In general, comparisons among spatial units should be avoided due to the scale problem (i.e., modifiable areal unit problem) (Openshaw 1984). This problem arises when information is grouped into different sized units and spatial arrangements. While we have presented the data together in Table 3, there was an evident decrease in some values as the area of the spatial unit increased and they were thus prone to the modifiable areal unit problem.

To assess the scalability of the methods adapted for this report, we informally analyzed the scaling relationship among the spatial units used. For this informal analysis, we sought to answer the basic question: Can habitat conditions derived from lek buffers be extrapolated to PACs or other analysis units? For the preliminary analysis, we hypothesized that changes in spatial unit extents result in linear changes in habitat condition estimates. We found that linear relationships were apparent for crop-pasture-hay, development, and sagebrush land cover among our spatial units and therefore lend themselves to prediction across spatial extents. Further research is needed to quantify the scaling relationships and understand how data resolution impacts the outcomes.

The sage-grouse has a range that extends across 11 states as well as two Canadian provinces. Considerable work has been completed to understand the local-, landscape-, and broad-scale conditions that explain sage-grouse habitat occupancy and population dynamics (Connelly et al. 2004; Hagen et al. 2007; Connelly et al. 2011; Coates et al. 2013); however, linking these studies with metrics that work with existing monitoring and management schemes is challenging. Doherty et al. (2010) demonstrated that sage-grouse habitat selection can be predicted using information derived at multiple spatial scales, but their analysis relied on plot-level data and remote sensing information. Acquisition of plot-level vegetation and sage-grouse data that is consistent across the entire range of sage-grouse for monitoring mid- to broad-scale spatial patterns and population trends is challenging, leaving remote sensing information as the best available choice for monitoring at these broader scales in the near future. Understanding the scaling properties of sage-grouse habitat conditions when using data derived from remote sensing can provide useful information for monitoring and adaptive management of sage-grouse across multiple relevant scales.

Data error

The datasets available to calculate habitat conditions were all modeled data. As such, they were, as George Box put it, wrong, but useful. Dataset utility comes from a clear understanding of the methods used to develop the data, the time range over which the data were applicable, and the repercussions of the resolution, among other factors. EVT data were developed at a regional scale for national- and regional-level analyses and therefore were less desirable for state-level and finer applications. Moreover, their accuracy at predicting arid system types has been questioned. For now, these data are useful for examining trends, but as higher resolution and more accurate data become available, EVT data should be phased out for state-level and finer applications.

In any large assessment in which many datasets are manipulated and analyzed, human error is always a possibility. To reduce the potential for processing errors, we created Python scripts that strictly record the processes used and can be used repeatedly. While they help to reduce error, they can be somewhat unstable between versions of ArcGIS.

Conclusions

Our analysis suggested that, in Oregon, sage-grouse habitat conditions at local scales are similar to those identified as important at regional scales; however, there are also important local differences, particularly surrounding historic leks. Oregon has seen some changes in habitat conditions, and they appear spatially dependent at the PAC scale in particular. Changes between 2001 and 2010 in crop-pasture-hay and development were slight; however the change in development was statistically significant, suggesting that attention should be paid to this threat in the future. The data used in this analysis were developed for change analysis and can be used to examine change over time, an important part of monitoring habitat conditions. Additional research is needed to understand the scaling properties of the data used and how assessments of this type relate to population dynamics.

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Appendix 1

Data Sources

- LANDFIRE: Land cover—Existing Vegetation (LF 1.2.0, 2010 [released in 2013] and LF 1.0.5 [www.landfire.gov])
- ODFW: Lek locations and sage-grouse Action Areas
- BLM: District boundaries
- SageCon: Modified population areas based on Schroeder et al. (2004)
- SageCon planning area boundary: This dataset was created by dissolving HUC 6 watersheds (12 digit HUCs) across SE Oregon to capture the occupied range of greater sage-grouse in the State.
- GEOMAC: Fire perimeters through 2014

Appendix 2

Table 8. Classes used for creating binary maps and the source classes used in this aggregation step.

SageCon-LANDFIRE generalized land cover class (0.0.1)	Classes lumped for this analysis	LANDFIRE land cover description	Knick et al. 2013 generalized land cover class
Crop-pasture-hay	Cultivated Crops and Irrigated Agriculture	Agriculture-Cultivated Crops and Irrigated Agriculture	Agriculture
	Fallow	Agriculture-Fallow	Agriculture
	General	Agriculture-General	Agriculture
	Pasture/Hay	Agriculture-Pasture/Hay	Agriculture
	Small Grains	Agriculture-Small Grains	Agriculture
Sagebrush	Big Sagebrush Shrubland	Inter-Mountain Basins Big Sagebrush Shrubland	Big Sagebrush Shrubland
	Big Sagebrush Steppe	Inter-Mountain Basins Big Sagebrush Steppe	Big Sagebrush Steppe
	Low Sagebrush	Columbia Plateau Low Sagebrush Steppe	Low Sagebrush
	Mountain Sagebrush	Inter-Mountain Basins Montane Sagebrush Steppe	Mountain Sagebrush
	Stiff (Rigid) Sagebrush	Columbia Plateau Scabland Shrubland	Stiff Sagebrush
Developed	Developed-General	Developed-General	Developed
	Developed-High Intensity	Developed-High Intensity	Developed
	Developed-Low Intensity	Developed-Low Intensity	Developed
	Developed-Medium Intensity	Developed-Medium Intensity	Developed
	Developed-Open Space	Developed-Open Space	Developed

Table 9. Crosswalk used to group LANDFIRE Existing Vegetation Types for the analyses.

LANDFIRE land cover class	LANDFIRE land cover description	Knick generalized land cover class	Knick generalized land cover description	SageCon-LANDFIRE generalized land cover class (0.0.1)
80	Agriculture-General	Agriculture	1	Crop-Pasture-Hay
81	Agriculture-Pasture/Hay	Agriculture	1	Crop-Pasture-Hay
82	Agriculture-Cultivated Crops and Irrigated Agriculture	Agriculture	1	Crop-Pasture-Hay
83	Agriculture-Small Grains	Agriculture	1	Crop-Pasture-Hay
84	Agriculture-Fallow	Agriculture	1	Crop-Pasture-Hay
2009	Northwestern Great Plains Aspen Forest and Parkland	Aspen Woodland	2	Aspen Woodland
2011	Rocky Mountain Aspen Forest and Woodland	Aspen Woodland	2	Aspen Woodland
12	Snow/Ice	Barren	3	Barren
31	Barren	Barren	3	Barren
2067	Mediterranean California Alpine Fell-Field	Barren	3	Barren
2068	North Pacific Dry and Mesic Alpine Dwarf-Shrubland or Fell-field or Meadow	Barren	3	Barren
2071	Sierra Nevada Alpine Dwarf-Shrubland	Barren	3	Barren
2083	North Pacific Avalanche Chute Shrubland	Barren	3	Barren
2136	Mediterranean California Alpine Dry Tundra	Barren	3	Barren
2143	Rocky Mountain Alpine Fell-Field	Barren	3	Barren
2144	Rocky Mountain Alpine Turf	Barren	3	Barren
2168	Northern Rocky Mountain Avalanche Chute Shrubland	Barren	3	Barren
2078	Colorado Plateau Blackbrush-Mormon-tea Shrubland	Blackbrush	6	Blackbrush
2210	Coleogyne ramosissima Shrubland Alliance	Blackbrush	6	Blackbrush
2034	Mediterranean California Mesic Serpentine Woodland and Chaparral	Chaparral	8	Chaparral
2096	California Maritime Chaparral	Chaparral	8	Chaparral
2097	California Mesic Chaparral	Chaparral	8	Chaparral
2098	California Montane Woodland and Chaparral	Chaparral	8	Chaparral
2099	California Xeric Serpentine Chaparral	Chaparral	8	Chaparral
2101	Madrean Oriental Chaparral	Chaparral	8	Chaparral
2103	Great Basin Semi-Desert Chaparral	Chaparral	8	Chaparral
2104	Mogollon Chaparral	Chaparral	8	Chaparral
2105	Northern and Central California Dry-Mesic Chaparral	Chaparral	8	Chaparral
2108	Sonora-Mojave Semi-Desert Chaparral	Chaparral	8	Chaparral
2110	Southern California Dry-Mesic Chaparral	Chaparral	8	Chaparral
2170	Klamath-Siskiyou Xeromorphic Serpentine Savanna and Chaparral	Chaparral	8	Chaparral
2092	Southern California Coastal Scrub	Coastal Scrub	27	Coastal Scrub
2128	Northern California Coastal Scrub	Coastal Scrub	27	Coastal Scrub
2014	Central and Southern California Mixed Evergreen Woodland	Conifer Forest	7	Conifer
2015	California Coastal Redwood Forest	Conifer Forest	7	Conifer
2018	East Cascades Mesic Montane Mixed-	Conifer Forest	7	Conifer

LANDFIRE land cover class	LANDFIRE land cover description	Knick generalized land cover class	Knick generalized land cover description	SageCon-LANDFIRE generalized land cover class (0.0.1)
	Conifer Forest and Woodland			
2020	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland	Conifer Forest	7	Conifer
2021	Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland	Conifer Forest	7	Conifer
2022	Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland	Conifer Forest	7	Conifer
2023	Madrean Encinal	Conifer Forest	7	Conifer
2024	Madrean Lower Montane Pine-Oak Forest and Woodland	Conifer Forest	7	Conifer
2026	Madrean Upper Montane Conifer-Oak Forest and Woodland	Conifer Forest	7	Conifer
2027	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	Conifer Forest	7	Conifer
2028	Mediterranean California Mesic Mixed Conifer Forest and Woodland	Conifer Forest	7	Conifer
2030	Mediterranean California Lower Montane Black Oak-Conifer Forest and Woodland	Conifer Forest	7	Conifer
2031	California Montane Jeffrey Pine(-Ponderosa Pine) Woodland	Conifer Forest	7	Conifer
2032	Mediterranean California Red Fir Forest	Conifer Forest	7	Conifer
2033	Mediterranean California Subalpine Woodland	Conifer Forest	7	Conifer
2035	North Pacific Dry Douglas-fir Forest and Woodland	Conifer Forest	7	Conifer
2036	North Pacific Hypermaritime Sitka Spruce Forest	Conifer Forest	7	Conifer
2037	North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest	Conifer Forest	7	Conifer
2038	North Pacific Maritime Mesic Subalpine Parkland	Conifer Forest	7	Conifer
2039	North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest	Conifer Forest	7	Conifer
2041	North Pacific Mountain Hemlock Forest	Conifer Forest	7	Conifer
2042	North Pacific Mesic Western Hemlock-Silver Fir Forest	Conifer Forest	7	Conifer
2043	Mediterranean California Mixed Evergreen Forest	Conifer Forest	7	Conifer
2044	Northern California Mesic Subalpine Woodland	Conifer Forest	7	Conifer
2045	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	Conifer Forest	7	Conifer
2046	Northern Rocky Mountain Subalpine Woodland and Parkland	Conifer Forest	7	Conifer
2047	Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	Conifer Forest	7	Conifer
2048	Northwestern Great Plains Highland White Spruce Woodland	Conifer Forest	7	Conifer
2049	Rocky Mountain Foothill Limber Pine-Juniper Woodland	Conifer Forest	7	Conifer
2050	Rocky Mountain Lodgepole Pine Forest	Conifer Forest	7	Conifer
2051	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Wood	Conifer Forest	7	Conifer

LANDFIRE land cover class	LANDFIRE land cover description	Knick generalized land cover class	Knick generalized land cover description	SageCon-LANDFIRE generalized land cover class (0.0.1)
2052	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland	Conifer Forest	7	Conifer
2053	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	Conifer Forest	7	Conifer
2054	Southern Rocky Mountain Ponderosa Pine Woodland	Conifer Forest	7	Conifer
2055	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Conifer Forest	7	Conifer
2056	Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Conifer Forest	7	Conifer
2057	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland	Conifer Forest	7	Conifer
2058	Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland	Conifer Forest	7	Conifer
2060	East Cascades Oak-Ponderosa Pine Forest and Woodland	Conifer Forest	7	Conifer
2061	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland	Conifer Forest	7	Conifer
2117	Southern Rocky Mountain Ponderosa Pine Savanna	Conifer Forest	7	Conifer
2165	Northern Rocky Mountain Foothill Conifer Wooded Steppe	Conifer Forest	7	Conifer
2166	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	Conifer Forest	7	Conifer
2167	Rocky Mountain Poor-Site Lodgepole Pine Forest	Conifer Forest	7	Conifer
2172	Sierran-Intermontane Desert Western White Pine-White Fir Woodland	Conifer Forest	7	Conifer
2174	North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	Conifer Forest	7	Conifer
2177	California Coastal Closed-Cone Conifer Forest and Woodland	Conifer Forest	7	Conifer
2178	North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest	Conifer Forest	7	Conifer
2179	Northwestern Great Plains-Black Hills Ponderosa Pine Woodland and Savanna	Conifer Forest	7	Conifer
2200	Pseudotsuga menziesii-Quercus garryana Woodland Alliance	Conifer Forest	7	Conifer
2205	Tsuga mertensiana-Abies amabilis Woodland Alliance	Conifer Forest	7	Conifer
2206	Pseudotsuga menziesii Giant Forest Alliance	Conifer Forest	7	Conifer
2208	Abies concolor Forest Alliance	Conifer Forest	7	Conifer
2227	Pseudotsuga menziesii Forest Alliance	Conifer Forest	7	Conifer
2228	Larix occidentalis Forest Alliance	Conifer Forest	7	Conifer
2229	Pinus albicaulis Woodland Alliance	Conifer Forest	7	Conifer
2230	Pinus sabiniana Woodland Alliance	Conifer Forest	7	Conifer
2231	Sequoiadendron giganteum Forest Alliance	Conifer Forest	7	Conifer
2232	Abies grandis Forest Alliance	Conifer Forest	7	Conifer
2074	Chihuahuan Creosotebush Desert Scrub	Creosote	9	Creosote
2087	Sonora-Mojave Creosotebush-White Bursage Desert Scrub	Creosote	9	Creosote

LANDFIRE land cover class	LANDFIRE land cover description	Knick generalized land cover class	Knick generalized land cover description	SageCon-LANDFIRE generalized land cover class (0.0.1)
2077	Chihuahuan Succulent Desert Scrub	Desert Scrub	28	Desert Scrub
2090	Sonoran Granite Outcrop Desert Scrub	Desert Scrub	28	Desert Scrub
2091	Sonoran Mid-Elevation Desert Scrub	Desert Scrub	28	Desert Scrub
2100	Chihuahuan Mixed Desert and Thorn Scrub	Desert Scrub	28	Desert Scrub
2109	Sonoran Paloverde-Mixed Cacti Desert Scrub	Desert Scrub	28	Desert Scrub
20	Developed-General	Developed	10	Developed
21	Developed-Open Space	Developed	10	Developed
22	Developed-Low Intensity	Developed	10	Developed
23	Developed-Medium Intensity	Developed	10	Developed
24	Developed-High Intensity	Developed	10	Developed
2181	Introduced Upland Vegetation-Annual Grassland	Exotic	12	Exotic
2182	Introduced Upland Vegetation-Perennial Grassland and Forbland	Exotic	12	Exotic
2183	Introduced Upland Vegetation-Annual and Biennial Forbland	Exotic	12	Exotic
2186	Introduced Upland Vegetation-Shrub	Exotic	12	Exotic
2180	Introduced Riparian Vegetation	Exotic Riparian	13	Exotic Riparian
2121	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	Grassland	15	Grassland
2122	Chihuahuan Gypsophilous Grassland and Steppe	Grassland	15	Grassland
2123	Columbia Plateau Steppe and Grassland	Grassland	15	Grassland
2129	California Central Valley and Southern Coastal Grassland	Grassland	15	Grassland
2130	California Mesic Serpentine Grassland	Grassland	15	Grassland
2131	California Northern Coastal Grassland	Grassland	15	Grassland
2132	Central Mixedgrass Prairie	Grassland	15	Grassland
2133	Chihuahuan Sandy Plains Semi-Desert Grassland	Grassland	15	Grassland
2134	Columbia Basin Foothill and Canyon Dry Grassland	Grassland	15	Grassland
2135	Inter-Mountain Basins Semi-Desert Grassland	Grassland	15	Grassland
2137	Mediterranean California Subalpine Meadow	Grassland	15	Grassland
2138	North Pacific Montane Grassland	Grassland	15	Grassland
2139	Northern Rocky Mountain Lower Montane-Foothill-Valley Grassland	Grassland	15	Grassland
2140	Northern Rocky Mountain Subalpine-Upper Montane Grassland	Grassland	15	Grassland
2141	Northwestern Great Plains Mixedgrass Prairie	Grassland	15	Grassland
2142	Columbia Basin Palouse Prairie	Grassland	15	Grassland
2145	Rocky Mountain Subalpine-Montane Mesic Meadow	Grassland	15	Grassland
2146	Southern Rocky Mountain Montane-Subalpine Grassland	Grassland	15	Grassland
2147	Western Great Plains Foothill and Piedmont Grassland	Grassland	15	Grassland
2149	Western Great Plains Shortgrass Prairie	Grassland	15	Grassland

LANDFIRE land cover class	LANDFIRE land cover description	Knick generalized land cover class	Knick generalized land cover description	SageCon-LANDFIRE generalized land cover class (0.0.1)
2150	Western Great Plains Tallgrass Prairie	Grassland	15	Grassland
2171	North Pacific Alpine and Subalpine Dry Grassland	Grassland	15	Grassland
2184	California Annual Grassland	Grassland	15	Grassland
2503	Chihuahuan Loamy Plains Desert Grassland	Grassland	15	Grassland
2504	Chihuahuan-Sonoran Desert Bottomland and Swale Grassland	Grassland	15	Grassland
2153	Inter-Mountain Basins Greasewood Flat	Greasewood	14	Greasewood
2012	Rocky Mountain Bigtooth Maple Ravine Woodland	Maple Woodland	21	Maple Woodland
2095	Apacherian-Chihuahuan Mesquite Upland Scrub	Mesquite	16	Mesquite
2111	Western Great Plains Mesquite Woodland and Shrubland	Mesquite	16	Mesquite
32	Quarries/Strip Mines/Gravel Pits	Mines	18	Mines
2127	Inter-Mountain Basins Semi-Desert Shrub-Steppe	Mixed Shrubland	19	Mixed Shrubland
2211	Grayia spinosa Shrubland Alliance	Mixed Shrubland	19	Mixed Shrubland
2082	Mojave Mid-Elevation Mixed Desert Scrub	Mojave Scrub	20	Mojave Scrub
2062	Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland	Mountain Mahogany	17	Mountain Mahogany
2216	Cercocarpus montanus Shrubland Alliance	Mountain Mahogany	17	Mountain Mahogany
-9999	No Data	No Data	0	No Data
2008	North Pacific Oak Woodland	Oak Shrubland	23	Oak Shrubland
2013	Western Great Plains Dry Bur Oak Forest and Woodland	Oak Shrubland	23	Oak Shrubland
2029	Mediterranean California Mixed Oak Woodland	Oak Shrubland	23	Oak Shrubland
2107	Rocky Mountain Gambel Oak-Mixed Montane Shrubland	Oak Shrubland	23	Oak Shrubland
2112	California Central Valley Mixed Oak Savanna	Oak Shrubland	23	Oak Shrubland
2113	California Coastal Live Oak Woodland and Savanna	Oak Shrubland	23	Oak Shrubland
2114	California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna	Oak Shrubland	23	Oak Shrubland
2118	Southern California Oak Woodland and Savanna	Oak Shrubland	23	Oak Shrubland
2201	Quercus garryana Woodland Alliance	Oak Shrubland	23	Oak Shrubland
2213	Quercus havardii Shrubland Alliance	Oak Shrubland	23	Oak Shrubland
2215	Quercus turbinella Shrubland Alliance	Oak Shrubland	23	Oak Shrubland
2217	Quercus gambelii Shrubland Alliance	Oak Shrubland	23	Oak Shrubland
2016	Colorado Plateau Pinyon-Juniper Woodland	Pinyon Juniper	24	Pinyon Juniper
2017	Columbia Plateau Western Juniper Woodland and Savanna	Pinyon Juniper	24	Pinyon Juniper
2019	Great Basin Pinyon-Juniper Woodland	Pinyon Juniper	24	Pinyon Juniper
2025	Madrean Pinyon-Juniper Woodland	Pinyon Juniper	24	Pinyon Juniper
2059	Southern Rocky Mountain Pinyon-Juniper Woodland	Pinyon Juniper	24	Pinyon Juniper
2115	Inter-Mountain Basins Juniper Savanna	Pinyon Juniper	24	Pinyon Juniper
2116	Madrean Juniper Savanna	Pinyon Juniper	24	Pinyon Juniper

LANDFIRE land cover class	LANDFIRE land cover description	Knick generalized land cover class	Knick generalized land cover description	SageCon-LANDFIRE generalized land cover class (0.0.1)
2119	Southern Rocky Mountain Juniper Woodland and Savanna	Pinyon Juniper	24	Pinyon Juniper
2202	Juniperus occidentalis Wooded Herbaceous Alliance	Pinyon Juniper	24	Pinyon Juniper
2203	Juniperus occidentalis Woodland Alliance	Pinyon Juniper	24	Pinyon Juniper
2151	California Central Valley Riparian Woodland and Shrubland	Riparian	25	Riparian
2152	California Montane Riparian Systems	Riparian	25	Riparian
2154	Inter-Mountain Basins Montane Riparian Systems	Riparian	25	Riparian
2155	North American Warm Desert Riparian Systems	Riparian	25	Riparian
2156	North Pacific Lowland Riparian Forest and Shrubland	Riparian	25	Riparian
2158	North Pacific Montane Riparian Woodland and Shrubland	Riparian	25	Riparian
2159	Rocky Mountain Montane Riparian Systems	Riparian	25	Riparian
2160	Rocky Mountain Subalpine/Upper Montane Riparian Systems	Riparian	25	Riparian
2162	Western Great Plains Floodplain Systems	Riparian	25	Riparian
2064	Colorado Plateau Mixed Low Sagebrush Shrubland	Low Sagebrush	11	Sagebrush
2065	Columbia Plateau Scabland Shrubland	Stiff Sagebrush	11	Sagebrush
2072	Wyoming Basins Dwarf Sagebrush Shrubland and Steppe	Low Sagebrush	11	Sagebrush
2079	Great Basin Xeric Mixed Sagebrush Shrubland	Low Sagebrush	11	Sagebrush
2080	Inter-Mountain Basins Big Sagebrush Shrubland	Big Sagebrush Shrubland	4	Sagebrush
2124	Columbia Plateau Low Sagebrush Steppe	Low Sagebrush	11	Sagebrush
2125	Inter-Mountain Basins Big Sagebrush Steppe	Big Sagebrush Steppe	5	Sagebrush
2126	Inter-Mountain Basins Montane Sagebrush Steppe	Mountain Sagebrush	22	Sagebrush
2220	Artemisia tridentata ssp. vaseyana Shrubland Alliance	Mountain Sagebrush	22	Sagebrush
2066	Inter-Mountain Basins Mat Saltbush Shrubland	Salt Desert Shrub	26	Salt Desert Shrub
2075	Chihuahuan Mixed Salt Desert Scrub	Salt Desert Shrub	26	Salt Desert Shrub
2081	Inter-Mountain Basins Mixed Salt Desert Scrub	Salt Desert Shrub	26	Salt Desert Shrub
2088	Sonora-Mojave Mixed Salt Desert Scrub	Salt Desert Shrub	26	Salt Desert Shrub
2093	Southern Colorado Plateau Sand Shrubland	Salt Desert Shrub	26	Salt Desert Shrub
2063	North Pacific Broadleaf Landslide Forest and Shrubland	Shrubland	29	Shrubland
2070	Rocky Mountain Alpine Dwarf-Shrubland	Shrubland	29	Shrubland
2076	Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	Shrubland	29	Shrubland
2084	North Pacific Montane Shrubland	Shrubland	29	Shrubland
2085	Northwestern Great Plains Shrubland	Shrubland	29	Shrubland
2086	Rocky Mountain Lower Montane-Foothill	Shrubland	29	Shrubland

LANDFIRE land cover class	LANDFIRE land cover description	Knick generalized land cover class	Knick generalized land cover description	SageCon-LANDFIRE generalized land cover class (0.0.1)
	Shrubland			
2094	Western Great Plains Sandhill Steppe	Shrubland	29	Shrubland
2106	Northern Rocky Mountain Montane-Foothill Deciduous Shrubland	Shrubland	29	Shrubland
2148	Western Great Plains Sand Prairie	Shrubland	29	Shrubland
2169	Northern Rocky Mountain Subalpine Deciduous Shrubland	Shrubland	29	Shrubland
2173	North Pacific Wooded Volcanic Flowage	Shrubland	29	Shrubland
2214	Arctostaphylos patula Shrubland Alliance	Shrubland	29	Shrubland
2385	Western Great Plains Wooded Draw and Ravine	Shrubland	29	Shrubland
2001	Inter-Mountain Basins Sparsely Vegetated Systems	Sparse Vegetation	30	Sparse Vegetation
2002	Mediterranean California Sparsely Vegetated Systems	Sparse Vegetation	30	Sparse Vegetation
2003	North Pacific Sparsely Vegetated Systems	Sparse Vegetation	30	Sparse Vegetation
2004	North American Warm Desert Sparsely Vegetated Systems	Sparse Vegetation	30	Sparse Vegetation
2006	Rocky Mountain Alpine/Montane Sparsely Vegetated Systems	Sparse Vegetation	30	Sparse Vegetation
2007	Western Great Plains Sparsely Vegetated Systems	Sparse Vegetation	30	Sparse Vegetation
11	Open Water	Water	31	Water
2157	North Pacific Swamp Systems	Wetland	32	Wetland
2161	Northern Rocky Mountain Conifer Swamp	Wetland	32	Wetland
2163	Pacific Coastal Marsh Systems	Wetland	32	Wetland
2495	Western Great Plains Depressional Wetland Systems	Wetland	32	Wetland