BUREAU OF LAND MANAGEMENT

Application of the Threat-Based Model Framework in the BLM Land Health Assessment and Evaluation Process in Oregon

Technical Note 452

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Authors:
Molly Anthony
Bureau of Land Management Oregon-Washington State Office
Portland, OR

Glenn Frederick
Bureau of Land Management Oregon-Washington State Office
Portland, OR

Angela Sitz
U.S. Fish and Wildlife Service
Bend, OR

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Abstract

The land health evaluation is a process that Bureau of Land Management district office staffs use on public rangelands to determine the health of the ecosystem and management interventions needed to maintain or improve the condition of renewable public resources. Many methodologies are used within the land health evaluation, and this report details a pilot study to explore the applicability and utility of incorporating the threat-based model approach into the land health evaluation process for a grazing allotment within Greater Sage-Grouse (*Centrocercus urophasianus*) habitat in Oregon. The threat-based model approach uses simplified ecosystem models to identify and map primary threats and determine potential management interventions. The study team found that the threat-based model supported the findings from the BLM's land health evaluation for the O'Keeffe allotment. The threat-based model approach offered another line of evidence in assessing upland standards. It also proved to be a valuable tool for communicating with stakeholders, as it provided a spatial depiction of habitat condition and threats through maps and a framework to link threats to management actions. The BLM needs to further apply and study this methodology, but there is potential to use the threat-based model to streamline the land health evaluation process and provide a consistent assessment framework across public and private lands.

Introduction

The Bureau of Land Management (BLM) manages large areas of rangelands in Oregon and throughout the western United States with the goal of ensuring their health and long-term capacity to support multiple public uses. Rangelands are healthy when ecological processes are functioning properly to maintain the structure, organization, and activity of the system over time (BLM 2001). Oregon rangelands encompass a portion of the western Great Basin, which includes habitat for Greater Sage-Grouse (hereafter sage-grouse). The health of these sagebrush ecosystems and the sage-grouse populations they support is greatly threatened by invasive weeds, fire, and juniper encroachment.

The BLM has developed standards and guidelines for rangeland health by state or region based on the fundamentals of rangeland health described in the Code of Federal Regulations (43 CFR subpart 4180). The standards provide a measure to determine land health and help the BLM, public land users, and others focus on a common understanding of acceptable resource conditions. The guidelines provide methods for working together to improve the health of the public lands. To determine whether standards are being met, the BLM conducts a land health assessment (LHA) to characterize the status of resource conditions. The staff conducts the LHA by gathering, synthesizing, and interpreting information from observations or data from inventories and monitoring. The BLM then evaluates the resource conditions in the LHA relative to the land health standards and guidelines (BLM 2001). The staff conducts a land health evaluation (LHE) to analyze and interpret the findings in the LHA and determine the degree of achievement of land health standards. The evaluation compares each site to its potential or capability.

Each set of standards and guidelines developed by the BLM must combine the basic precepts of physical function and biological health with relevant elements of law, such as those relating to water quality and plant and animal populations and communities. The BLM developed five standards that apply to public rangelands across Oregon and Washington (BLM 1997):

- Standard 1. Watershed Function–Uplands: Upland soils exhibit infiltration and permeability rates, moisture storage, and stability that are appropriate to soil, climate, and landform.

- Standard 2. Watershed Function–Riparian/Wetland Areas: Riparian-wetland areas are in properly functioning physical condition appropriate to soil, climate, and landform.

- Standard 3. Ecological Processes: Healthy, productive, and diverse plant and animal populations and communities appropriate to soil, climate, and landform are supported by ecological processes of nutrient cycling, energy flow, and the hydrologic cycle.

- Standard 4. Water Quality: Surface water and groundwater quality, influenced by agency actions, complies with State water quality standards.

- Standard 5. Native, T&E [threatened and endangered], and Locally Important Species: Habitats support healthy, productive, and diverse populations and communities of native plants and animals (including special status species and species of local importance) appropriate to soil, climate, and landform.

The BLM incorporates multiple methodologies, such as the assessment, inventory, and monitoring (AIM) strategy (Toevs et al. 2011; Kachergis et al. 2020) and the sage-grouse habitat assessment

framework (HAF) (Stiver et al. 2015), into the LHA and LHE process. The State of Oregon adopted a methodology using threat-based models (TBMs) (also called simplified state-and-transition models) to assess sagebrush ecosystem condition and sage-grouse habitat on private lands (SageCon 2015). The original application of TBMs in developing Candidate Conservation Agreements with Assurances for sage-grouse on private lands has since expanded to include lands administered by the BLM in Oregon (USFWS 2014).

Objectives and Scope

Conducting an LHA and LHE is labor intensive, and the ecological concepts addressed are complex and can be difficult to convey to a broad audience, including BLM permittees, stakeholder groups, and other agencies. It can also be difficult to communicate the connection between the results of these evaluations and any management recommendations they contain for modifications to existing land use authorizations, restoration actions, or monitoring.

The use of multiple assessment methodologies has been confusing to some stakeholders, especially when the BLM first implemented those methodologies. In addition, since the release of the BLM's Oregon Greater Sage-Grouse Approved Resource Management Plan Amendment (ARMPA)

(BLM 2015), some partners in Oregon have raised concerns about the implementation of the HAF and its application to grazing permit renewals and authorizations of other uses in areas designated as sage-grouse habitat.

While BLM policy addresses many of these concerns, in 2016 an interagency group determined the need to explore the applicability and utility of incorporating TBMs into the LHA and LHE process to address other concerns. The group designed a pilot study to investigate the potential role of TBMs in the LHA/LHE process for a grazing allotment containing sage-grouse habitat in Lake County, Oregon. This report focuses primarily on the upland standards (1, 3, and 5) and the assessment portion of the process.

Methods

Pilot Study Location

The pilot study focused on the 54,037-acre O'Keeffe allotment in the BLM's Lakeview District in south-central Oregon (figure 1). The allotment contains 16 pastures and several grazing exclosures. The BLM manages 51,442 acres of the allotment, and the remaining 2,595 acres are privately owned. We selected this allotment for the pilot study due to the timing of the grazing permit renewal, currently available data, and enrollment of the allotment in a Candidate Conservation Agreement in 2013. The BLM's Lakeview District

interdisciplinary team completed the LHE for the O'Keeffe allotment in 1999 and updated it in 2017.

Threat-Based Model Assessment Methods

TBMs help identify and prioritize management actions to address the primary threats to the sagebrush ecosystem: wildfire, invasive annual grasses, and juniper encroachment (Johnson et al. 2019b). TBMs encompass a framework of
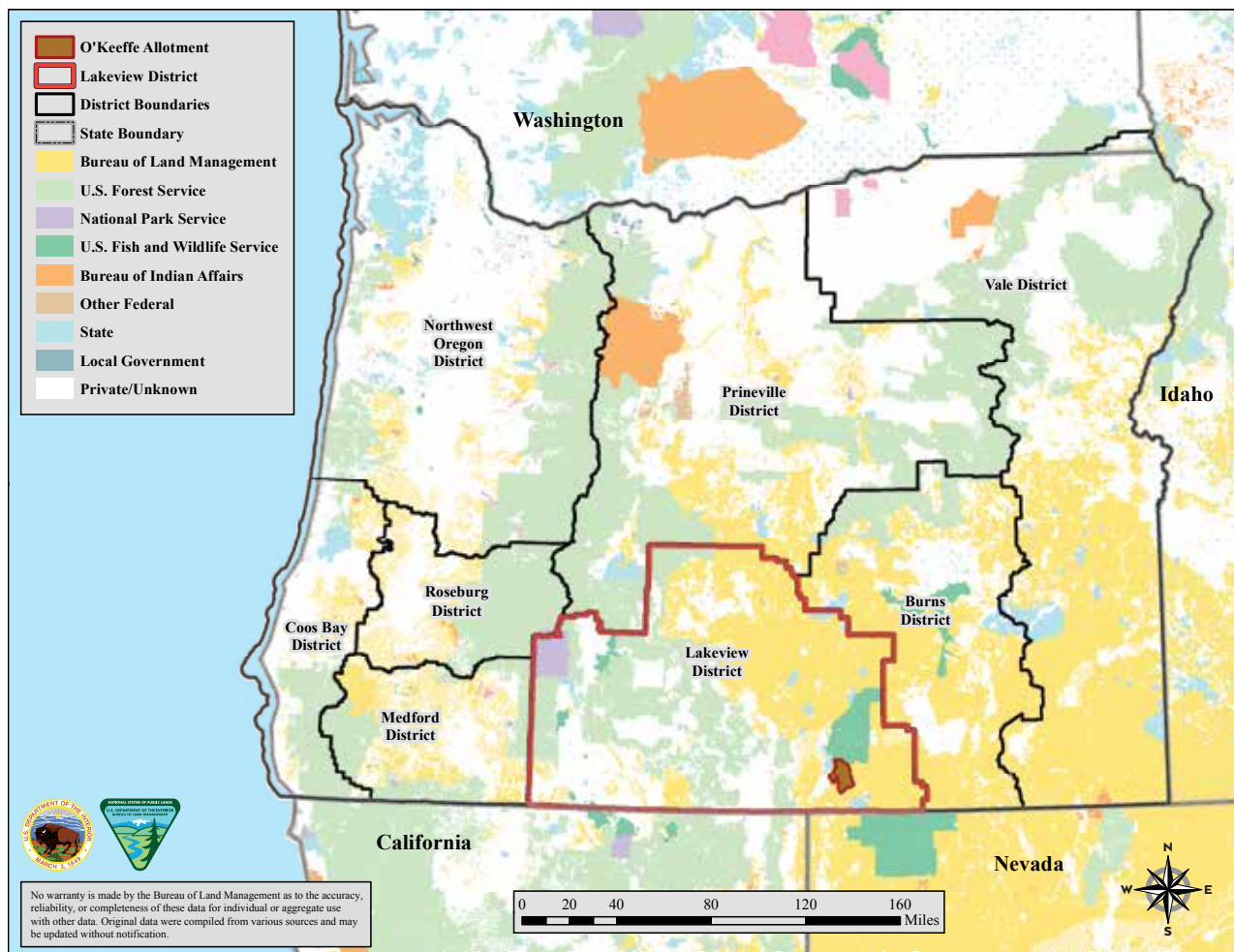
Figure 1. Pilot study area location within the BLM Lakeview District, Oregon.

steps that include establishing management objectives, understanding the relevant ecology and threats, spatially delineating ecological states and apparent trend, and identifying management actions. Candidate Conservation Agreements on BLM-administered lands and Candidate Conservation Agreements with Assurances on private lands throughout mapped sage-grouse habitat in central and southeastern Oregon apply this approach. Further, the State of Oregon's Sage-Grouse Action Plan (SageCon 2015) relies on TBMs to characterize rangeland vegetation condition across the state and tie site-level vegetation conditions to management objectives and practices.

TBMs categorize ecological states using a letter grade representing their condition and the threat expressed: invasive annual grass, juniper encroachment, or both invasive annual grass and juniper encroachment (dual threats). Ecological states within the TBM represent a spectrum ranging from intact native plant communities (A and B) to areas compromised by juniper and invasive annual grass threats at levels that may be addressed through management actions

(C and some D) to areas compromised to a degree that may not be recoverable (some D and E) (table 1). The interdisciplinary team uses field-based mapping or remotely sensed map products to map these areas across the landscape of interest.

The interdisciplinary team conducts field visits within each mapped polygon and estimates apparent trend (Johnson et al. 2019a, 2019b) using the Upland Ecological State Documentation Form (figure 2). Apparent trend estimates attempt to characterize the trend for each primary threat in three categories:

- Declining trend – the threat is escalating (or may escalate in the near future)

- Increasing or stable apparent trend – the threat is diminishing in significance

- Unclear apparent trend

The interdisciplinary team also identifies areas of "persistently unsuitable habitat" that include sites without the potential to support sagebrush or associated plant communities, areas with land use conversion (agriculture, development, etc.), or nonrangeland areas (playas, open water, etc.).

Table 1. Descriptions of conditions and threats for each TBM ecological state.

Ecological State: Model	Description	Sagebrush cover	Invasive annual grass: Perennial grass ratio	Juniper
A	Intact native shrubland	>10%	<1:1	Absent
B	Intact native grassland	<10%	<1:1	Absent
C: Invasive annual grass threat	Shrubland with annual grass understory	>10%	>1:1	Absent
C: Dual threats	Shrubland with encroaching juniper and annual grass understory	>10%	Any	Phase 1
C: Juniper threat	Shrubland with encroaching juniper	>10%	<1:1	Phase 1
D: Invasive annual grass threat	Annual grassland	<10%	>1:1	Absent
D: Dual threats	Shrubland or grassland with encroaching juniper and annual grass understory	<10%	>1:1	≤ Phase 1
D: Juniper threat	Juniper woodland with native perennial understory	<10%	<1:1	≥ Phase 1
E: Dual threats	Juniper woodland with annual grass understory	<10%	>1:1	≥ Phase 2
E: Juniper threat	Juniper woodland with denuded understory	<10%	Denuded	≥ Phase 2

Upland Ecological State Documentation Form

<div align="right">BLM-Updated 05/23/16</div>

General Information	Observer		Date		Previous Precip. (past year)		Allotment		Pasture
					□High □Low □Avg. □Unknown				

Ecological Model[1] & State

Threat-based Ecological Model (circle) | **Ecological State (circle)**

IAG[2]   *IAG/Juniper*   *Juniper* | A   B   C   D   E   Other_____

GIS datasets used to map ecological state polygon described on this form. (Check all that apply and specify source)

□ ESD	□ NAIP imagery	□ R & R (Chambers)	□ Fire perimeters	□ GRSG seasonal habitat
□ Conifer cover	□ Sagebrush cover	□ Invasive plants	□ Soils	□ Other

Habitat Acreage within polygon

PHMA		**GHMA**		**SFA**		**Other**	

Random Meander Track/Photo Point Location(s)

Random Meander GPS Track file[3]	

Photo 1 (coordinates)		**Photo 4** (coordinates)	
Photo 2 (coordinates)		**Photo 5** (coordinates)	
Photo 3 (coordinates)		**Photo 6** (coordinates)	

Vegetation

Vegetation Type:	

Dominant Plant Species

Grasses	Forbs	Shrubs	Trees

Estimated average density of mature, large perennial bunchgrasses				individuals/m^2

	No	Yes	If, yes	
Sagebrush present?			Species	
			Estimated sagebrush cover	
Juniper present?			Estimated juniper cover	
			Encroachment phase[4]	
Exotic annual grass present?			Species	
			Invasion phase[5]	
Infestations mapped?			Date mapped:	
Other weeds present?			Species	
Infestations mapped?			Date mapped:	
Key area(s)[6] identified in ecological state stratum?			Coordinates:	

Potential Threats[7] (check all that apply)

□ Fragmentation	□ Juniper encroachment	□ Lack of fire	□ Recreation	□ Feral horses
□ Wildfire	□ Livestock grazing management	□ Drought	□ Predation	□ Insecticide
□ Vegetation treatment	□ Invasive vegetation	□ Flooding	□ WNv	□ Other

Footnotes

[1] Ecological models are based on the predominant threats posed at the site: invasive annual grasses, both invasive annual grasses and juniper expansion, or primarily juniper expansion. These models correspond to those previously termed "low elevation", "mid elevation", and "high elevation", respectively.

[2] IAG = Invasive Annual Grass

[3] If used, the GPS track of the random meander should be permanently archived for assessment repeatability. See Nelson, J.R. 1985. Rare plant surveys: techniques for impact assessment. Natural Areas Journal 5(3): 18-30.

[4] See Miller, R.F., Bates, J.D., Svejcar, T.J., Pierson, F.B., and Eddleman, L.E. 2007. Western Juniper Field Guide: Asking the Right Questions to Select Appropriate Management Actions: U.S. Geological Survey Circular 1321, 61 p.

[5] **Phase I:** Interspaces primarily bare ground (≥90% interspaces bare ground) and multiple bunchgrass age classes represented; generally associated with Ecological States A & B. **Phase II:** Exotic annual grasses present at intermediate levels in interspaces (≤ 50% interspaces occupied by exotic annual grasses) and multiple bunchgrass age classes represented; generally associated with Low and Mid Elevation Ecological States A & B that are at risk of conversion to Low Elevation Ecological States C & D or Mid Elevation Ecological State E, respectively. **Phase III:** Interspaces primarily occupied by exotic annual grasses (>50% interspaces occupied by exotic annual grasses) and ≤ 1 bunchgrass age class represented; generally associated with Low Elevation Ecological States C & D and Mid Elevation Ecological States D & E.

Figure 2. Upland Ecological State Documentation Form.

	Factors to consider[8]:		
Estimate of Apparent Trend	Will current grazing management (including wild horses) maintain/promote desirable vegetation?	**Yes** Rest/recovery is planned during periods when desirable vegetation is actively growing. Forage demand is in balance with forage supply.	□ **Stable** or □ **Increasing**
		No Continuous (every year) use during the period when desirable vegetation is actively growing. Forage demand consistently > supply.	□ **Decreasing**
	For IAG and IAG/Juniper models: If shrubs are present, what is the dominant vegetation in the shrub interspaces?[9]	**Mature deep-rooted perennial bunchgrass (not Sandberg bluegrass, unless it is a Sandberg's site)**	□ **Stable** or □ **Increasing**
		Exotic annuals	□ **Decreasing**
	For IAG and IAG/Juniper models: If shrubs are largely absent, what occupies the interspaces between perennial bunchgrasses?[9]	**Bare ground/litter/desired forbs**	□ **Stable** or □ **Increasing**
		Exotic annuals	□ **Decreasing**
	For IAG/Juniper and Juniper models: Are juniper seedings and/or leader growth common?	**Yes**	□ **Decreasing**
		No	□ **Stable** or □ **Increasing**
	Is there evidence of recruitment of desired plants (i.e. multiple age classes/functional groups present) or is all interspace filled with desired plants?	**Yes**	□ **Stable** or □ **Increasing**
		No	□ **Decreasing**
	How would the plant community most likely respond after wildfire?	Perennial bunchgrasses are primarily located under shrub canopies and thus are more susceptible to mortality during a fire event.	□ **Decreasing**
		Perennial bunchgrasses are located within the shrub interspaces and thus more likely to survive a fire event.	□ **Stable** or □ **Increasing**
	Observed apparent trend (circle)	*Upward*　　　*Stable*　　　*Downward*　　　*Not apparent*[8]	

Rationale for ecological state determination and trend[10]	

Other relevant data (legacy or collected concurrently)	□ **AIM**	□ **HAF**	□ **Rangeland Health**	□ **Utilization**	□ **ESD**	□ **Trend**	□ **Other** _____
	□ Legacy □ Concurrent	□ Legacy □ Concurrent	□ Legacy □ Concurrent	□ Legacy □ Concurrent	□ Legacy □ Concurrent	□ Legacy □ Concurrent	□ Legacy □ Concurrent

Additional Notes	

Footnotes, continued

[6] A "key area" is a representative area in the pasture pertaining to a specific management question.

[7] Potential threats are those that either currently exist or pose an imminent threat in the foreseeable future.

[8] See *Estimating Apparent Trend* handout for guidance on developing rationale for observed apparent trend.

[9] Exotic annual grass (or its seed) is present in most sagebrush/bunchgrass plant communities. Be aware that some years present ideal climatic conditions for the expression of exotic annuals, which can bias observations related to plant community dominance and decisions about apparent trend. The density of perennial bunchgrasses should be the focus of observations because it fluctuates much less than the abundance of exotic annual grasses in response to inter-annual variation in climate. Rule of thumb: if you can relatively easily step from one perennial bunchgrass to another, their density is likely adequate to suggest an apparent stable or upward trend. Conversely, if you must leap from bunchgrass to another, the opposite is most likely true; particularly if exotic annuals fill the spaces between bunchgrasses.

[8] Overall trend is "Not apparent" if "increasing" and "decreasing" is indicated for an equal number of the individual factors considered to determine the overall trend.

[10] Explain the ecological state and apparent trend determination made. List any factors considered in addition to those listed on the front of this page.

In October 2015, the BLM staff piloted using the TBM approach to inform the Candidate Conservation Agreement for the O'Keeffe allotment. The TBM process consisted of three steps.

Map Ecological States on Desktop

The BLM Lakeview District wildlife staff created preliminary TBM maps using a desktop geographic information system analysis prior to visiting the allotment. Staff members delineated ecological states based on pasture boundaries and used a conifer cover map and Esri World Imagery to look for visible differences in vegetation cover across the pastures. The primary vegetative components analyzed in this step were sagebrush cover and juniper cover, and the minimum polygon size was set at 50 acres.

Verify and Refine Ecological State Map in the Field

The BLM Lakeview District interdisciplinary team conducted an initial field visit to ground truth the desktop map and identify discrepancies between the ground-based and office-based data, resulting in updates and refinements to the desktop map. The interdisciplinary team also completed the Upland Ecological State Documentation Form in the field for each assessed polygon. Following the initial field visit, a group including the permittee and staff from the BLM and other agencies again visited the allotment to verify and further refine the map. The team further updated the polygons based on field evaluation, consideration of long-term trend data, permittee knowledge, and incorporation of a remotely sensed map of annual grass cover (Xian et al. 2015).

Identify Other Threats and Conservation Measures

In addition to mapping primary ecological threats, the TBM methodology prompts managers to assess several other threats to sage-grouse, including fragmentation, wildfire, vegetation treatments (e.g., sagebrush removal and nonnative perennial bunchgrass plantings), improper livestock management, lack of fire, drought, catastrophic flooding, recreation, predation,

West Nile virus, and wild horses (USFWS 2013, SageCon 2015). The TBM also identifies a suite of conservation measures tied to each ecological state and threat level that promotes maintenance of, or desirable transition between, ecological states, including juniper management, invasive annual grass control, and grazing management, among others. The interdisciplinary team identified secondary threats and potential conservation measures during field visits to the O'Keeffe allotment.

BLM Land Health Assessment Methods

The BLM conducts the LHA by gathering, synthesizing, and interpreting information from observations or data from inventories and monitoring. For the O'Keeffe LHA, the interdisciplinary team used various data sources and assessment methods.

Gather Plot Data

BLM Assessment, Inventory, and Monitoring Data
The BLM uses an integrated, cross-program approach for the assessment, inventory, and monitoring of renewable resources. The goals of the BLM's AIM strategy are to 1) report on the status and trends of public rangelands at multiple scales of inquiry, 2) report on the effectiveness of management actions, and 3) provide the information necessary to implement adaptive management. The AIM strategy uses a set of core indicators and consistent standardized methods to understand the status, condition, and trend of ecosystems over time (Herrick et al. 2017). The core AIM data collection methods include line-point intercept measurements for vegetation cover and height along three transects; canopy gap intercept measurements for spatial distribution of vegetation and bare ground; plot-level plant species inventory; soil stability test; and plot characterization, including soil composition and photos along each transect. Supplemental methods to measure visual obstruction and predominant sagebrush shape were also employed. Analyses of AIM data summaries can provide quantitative insights to many areas of

interest, and AIM data is widely used in remotely sensed map products (Henderson et al. 2019, Jones et al. 2018, Xian et al. 2015). For this pilot study, the team used data from AIM plots to provide information on vegetation composition and inform sage-grouse habitat suitability ratings.

In many cases, the AIM strategy is to establish plots in a probabilistic manner and locate them so that multiple sample designs can be used together to estimate conditions across an area of interest. Plot weighting facilitates proportional area estimates of condition class, such as those used in the HAF. The team used plots from multiple AIM sample designs in the Beatys Butte area and the O'Keeffe allotment, but they were collected with consistent methodology and pooled for use in the LHA.

Lakeview District Trend Plots
There are 21 long-term trend photo plots within the O'Keeffe allotment. The team selected these plot locations as "key areas" (BLM 1999) because of their value as a monitoring point for grazing use that reflects the overall grazing management across the allotment. The BLM established 15 of these plots between 1964 and 1975 and established the remainder between 1987 and 2000, with photo monitoring conducted since the initial plot establishment. Fifteen of the 21 plots had associated vegetation transects (typically added in 2012 for the plots established in the 1960s and 1970s), which provide data on vegetation cover and frequency. Typically, the BLM repeats vegetation sampling and photo monitoring every 3 to 5 years.

Assess Standard 1: Upland Watershed Function

Standard 1 evaluates whether upland soils exhibit infiltration and permeability rates, moisture storage, and stability that are appropriate to soil, climate, and landform. The focus is on the basic physical functions of upland soils to support plant growth, maintain or develop plant populations and communities, and promote dependable flows of quality water from the watershed. Potential indicators for evaluating this standard include: amount and distribution of plant

cover, amount and distribution of plant litter, accumulation/incorporation of organic matter, amount and distribution of bare ground, amount and distribution of rock, plant composition and community structure, thickness and continuity of soil A horizon, character of microrelief, presence and integrity of biotic crusts, root occupancy of the soil profile, biological activity, and absence of accelerated erosion and overland flow (BLM 1997).

An ecological site inventory (ESI) (Habich 2001) was completed in 1988, which identified vegetation communities within the O'Keeffe allotment. The team used information derived from the ESI to determine the condition of the soils and vegetation for the allotment. The ESI recorded a soil surface factor rating, an observed apparent trend rating, and an ecological condition rating for each vegetation community.

We sampled 18 AIM plots on the O'Keeffe allotment yielding measures of vegetation composition, litter and bare ground cover, vegetation foliar cover, and soil stability. The data collected at AIM points provides quantitative measures that correlate with qualitative indicators of rangeland health (Pellant et al. 2005), such as bare ground and proportion of soil surface covered by canopy gaps larger than 8 inches. In turn, these quantitative assessment indicators support the qualitative assessment of the rills, water flow patterns, and bare ground, which make up 3 of the 17 indicators of rangeland health.

The team examined photos and vegetation data from the available long-term trend plots and summarized in the LHA. We compared the TBM map to data from the long-term trend plots and AIM plots. We also compared dominant functional groups identified through the TBM map to vegetation composition estimated from monitoring plots located within the TBM polygon to determine if the TBM ecological state was representative of plot data and vice versa. In addition, we examined actual livestock use with associated utilization levels for each pasture to determine if grazing had exceeded the authorized use levels and could lead to accelerated soil erosion.

Assess Standard 3: Ecological Processes

Standard 3 evaluates if the health, productivity, and diversity of plant and animal populations and communities appropriate to the soils, climate, and landforms are supported by the ecological processes of nutrient cycling, energy flow, and the hydrologic cycle. The focus is an evaluation of the extent to which plant communities are supporting an appropriate nutrient and energy cycle relative to the site potential, which in turn supports appropriate animal communities. Potential indicators for assessing standard 3 include: plant composition and community structure; accumulation, distribution, and incorporation of plant litter and organic matter in the soil; animal community structure and composition; root occupancy in the soil profile; and biological activity, including plant growth, herbivory, and rodent, insect, and microbial activity (BLM 1997).

The team used the same data from the ESI, long-term trend plots, and AIM plots for standard 1 (except for soil surface factor) to evaluate the composition, health, and vigor of vegetation for standard 3. We also considered seral stage information collected through a similarity index conducted as part of the ESI for this evaluation. The TBM mapping provided additional information on vegetation community composition by functional group. Additionally, we examined actual livestock use with associated utilization data for each pasture to determine if grazing had exceeded the authorized use level and could reduce plant vigor or change plant composition.

The team also assessed wildlife habitat for this standard based on the condition of plant communities. Diverse, productive plant communities imply that hydrology, nutrient cycling, and energy flow are properly functioning, which in turn maintains appropriate wildlife habitat for the area. We assessed wildlife habitat for some special status species (such as sage-grouse) under standard 5.

Assess Standard 5: Native, Threatened, Endangered, and Locally Important Species

Standard 5 evaluates if habitats within the analysis area support healthy, productive, and diverse populations of native plants and animals (including special status species and species of local importance) appropriate to the soil, climate, and landform. The focus is primarily on retaining or restoring native plant and animal communities (especially threatened, endangered, and special status species) that are distributed across the landscape, have an appropriate mixture of age classes, and are sustainable. Potential indicators for evaluating this standard include plant community composition, age class distribution, and productivity; animal community composition and productivity; habitat elements; spatial distribution of habitat; habitat connectivity; and population stability and resilience. For the purposes of this report, we only discuss the sage-grouse portion of standard 5. Other species addressed in the LHA and LHE include mule deer, pronghorn, California bighorn sheep, bald eagles, pygmy rabbits, broadtooth monkeyflower, and Cusick's giant hyssop.

The ARMPA (BLM 2015) establishes indicators and measurable objectives to meet desired habitat conditions for sage-grouse in Oregon. The HAF (Stiver et al. 2015) helps determine the suitability of those indicators and objectives for sage-grouse habitat at nested spatial scales. Habitat suitability ratings provide the primary line of evidence to inform the sage-grouse portion of standard 5 (BLM 2018). In addition, BLM policy directs field offices to consider using additional data sources and information as appropriate, such as range trend plots and ecological state maps, to inform the assessment of habitat indicators. The HAF defines habitat at the broad scale (first order) by the extent of sage-grouse distribution rangewide, informed by the evaluation of sage-grouse numbers at leks distributed across the landscape. Indicators of habitat suitability are evaluated at the other three scales and vary with the order of sage-grouse habitat selection (Johnson 1980): second order (mid scale), third order (fine scale), and fourth order (site scale). Note that the fourth order, or site scale, in the HAF is spatially broader than other

areas in this document referred to as "sites," such as ecological sites, plot sites (individual points), lek sites, or treatment sites. The O'Keeffe allotment lies entirely within the third-order area (figure 3), and while an allotment is not a biological unit, the HAF provided geographic context to the sage-grouse habitat within the allotment and helped the BLM to determine which, if any, seasonal habitat conditions appeared to be limiting the population. The following methods were used to delineate and assess habitat at these three scales (see BLM 2017a for more detail).
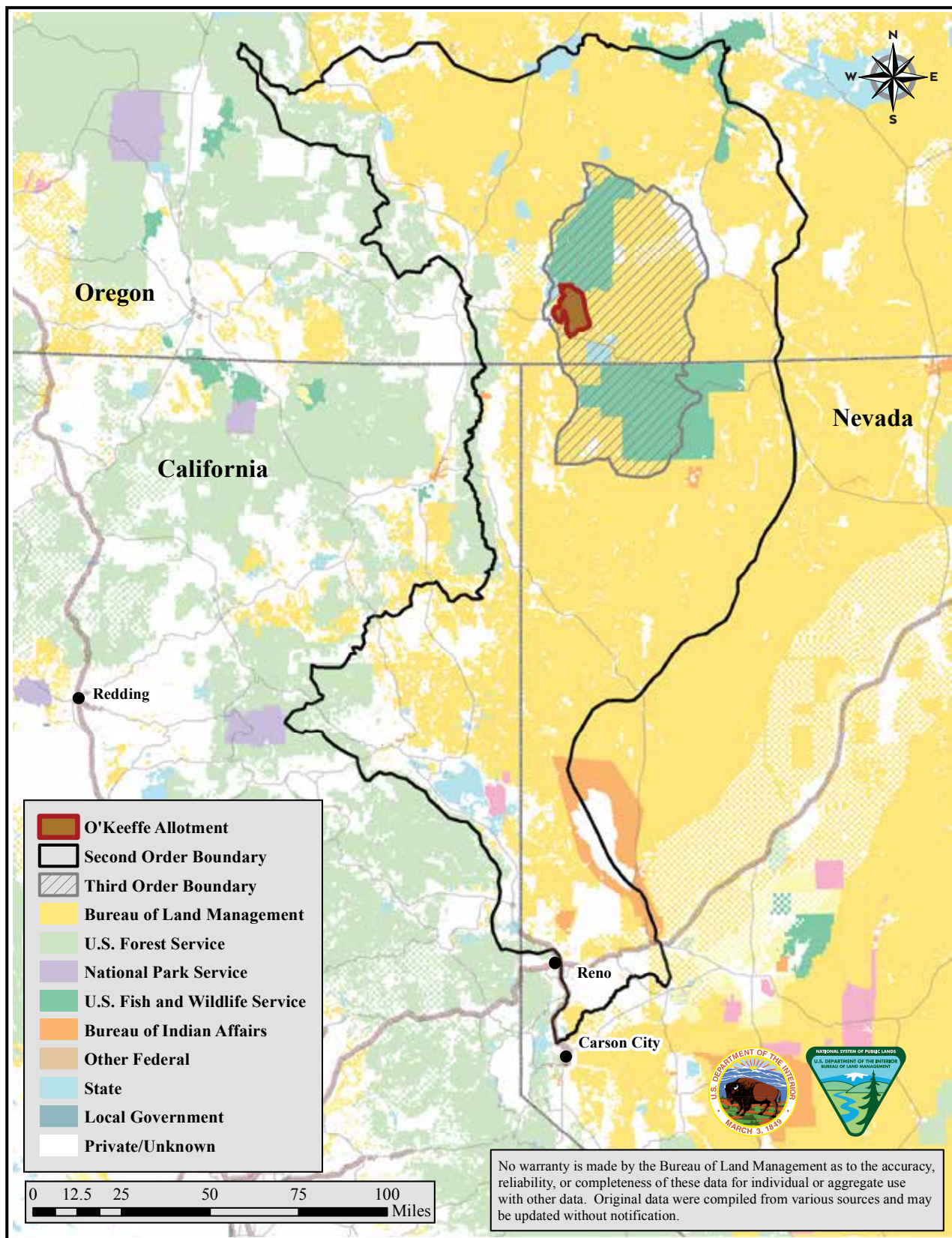
Second-Order (Mid-Scale) Habitat Assessment

The second-order habitat assessment described habitat characteristics linked to bird dispersal capabilities, including habitat availability, patch size and number, patch connectivity, linkage area characteristics, landscape matrix and edge effects, and anthropogenic disturbances (Stiver et al. 2015). The BLM, in coordination with the Oregon Department of Fish and Wildlife and Nevada Department of Wildlife, delineated the Warner-Meinzer second-order analysis area (11.7 million acres) (figure 3), including occupied areas (4.9 million acres), based on topography, lek locations, telemetry data, modeled sage-grouse dispersal resistance data, remotely sensed maps, and expert local knowledge. The team mapped current and potential suitable sagebrush cover using remotely sensed land cover data. We

delineated occupied areas using 4-mile lek buffers and sage-grouse telemetry locations. We delineated habitat patches using a 3.1-mile radius moving window analysis. The team measured patch connectivity using mean distance to the nearest occupied patch. We intersected occupied habitat patches with the BLM disturbance compilation dataset to calculate the density and area of disturbance features.

Third-Order (Fine-Scale) Habitat Assessment

The third-order habitat assessment characterized sage-grouse seasonal habitats within home ranges, including seasonal habitat availability, seasonal use area connectivity, and anthropogenic disturbances (Stiver et al. 2015). The BLM, in coordination with Oregon Department of Fish and Wildlife and Nevada Department of Wildlife, delineated the third-order boundary (figure 3) using topographic features, lek locations, telemetry data, modeled resistance data, and expert knowledge. We delineated breeding, summer, and winter habitats within the area from interpolation models (Henderson 2016, Oyarzun 2017) and local expert knowledge. We used the suitable and potential habitat datasets and the occupancy dataset developed for the second-order analysis in the third-order analysis. Seasonal use area connectivity measured the ratio of the amount of overlap between seasonal use areas to the total area of the seasons combined.

Figure 3. Location of the O'Keeffe allotment within the Greater Sage-Grouse HAF second-order and third-order habitat analysis areas in Oregon, Nevada, and California.

Fourth-Order (Site-Scale) Habitat Assessment

Seasonal habitats mapped for the third-order analysis establish the geographic extent for the fourth-order assessment (figure 3). However, in the pilot study, we considered only the Oregon portion of the Beatys Butte third-order analysis area because fourth-order suitability ratings were not available for BLM lands in Nevada. The interdisciplinary team assessed indicators of seasonal habitat (BLM 2015; table 2-2) collected at 49 AIM plots in 2016. The plots used to rate suitability for a season intersected the mapped seasonal habitat, and sampling occurred during the appropriate seasonal use period (i.e., spring: March 1 to June 30; summer: July 1 to September 30). We used all AIM plots to assess winter habitat suitability regardless of sample date since the primary habitat indicators, sagebrush cover and sagebrush height, do not vary with season. We considered the entire suite of seasonal habitat indicators when rating the overall suitability of a plot. We documented ecological site potential of the plot to facilitate interpretation of the ratings in the LHA. Additional analysis leveraged the probabilistic sample designs underlying the assessed plots and estimated the percent of each seasonal habitat within the sample frame or inference space (i.e., BLM-managed lands) that was suitable, marginal, or unsuitable. We generated confidence intervals to disclose the amount of uncertainty in the proportional area estimates.

The team assessed lek habitat suitability using a combination of remotely sensed data, communications with local experts, and other existing data. We evaluated leks either on the ground during 2017 lek counts (25 leks) or through geographic information system analysis (123 leks).

O'Keeffe Allotment Habitat Assessment

For standard 5, we assessed sage-grouse habitat suitability using the multiscale HAF. However, the scale of this allotment-level LHA does not align with these scales; it represents a smaller area than the fourth-order (smallest scale) HAF analysis. Of the 18 AIM plots sampled within the O'Keeffe allotment, 15 fell within mapped seasonal habitat and were rated for their suitability based on the procedure outlined for the fourth order. While the full HAF analysis is broader than the allotment level, plot suitability ratings helped to draw conclusions about the suitability of seasonal habitats, identify any limiting habitats, and highlight any areas needing additional monitoring within the allotment. We also used other information, such as precipitation data, vegetation data from long-term trend plots, and TBM maps, to inform standard 5 for the O'Keeffe allotment.

Results and Discussion

This pilot study sought to understand if TBMs provide a valuable additional line of evidence to inform, strengthen, and expedite the BLM LHE process.

Threat-Based Model Assessment Results

The team mapped privately owned and BLM-managed acres in the O'Keeffe allotment into 47 polygons and assessed threats to 41 using the TBM approach (table 2 and figure 4). Six polygons (categorized as "Other" in table 2) consisted of rocky outcroppings or naturally occurring areas of juniper (per ecological site descriptions). While approximately 55 percent of the allotment is state A that has vegetation components of sage-grouse habitat, 30 percent (8,447 acres) of these acres had a declining apparent trend. Similarly, most (83 percent) of the other mapped polygons with assessed threats had a declining trend, raising concern over the long-term persistence of not only those areas degraded by threats but also those areas in relatively healthy condition. We classified 6.3 percent of the allotment acreage that was dominated by crested wheatgrass as state B. These converted systems provide the ecological function of holding soils and limiting annual grass invasion; however, they generally lack diversity in forbs and insects (key components required for sage-grouse) and had an estimated declining apparent trend because of extensive annual grass patches found within or adjacent to the polygons.

The team classified one-quarter of the allotment as state C. All but one state C polygon had an estimated declining apparent trend, indicating that condition will likely worsen without management action.

Table 2. The number of map units (mapped polygons), acres, and percent of the O'Keeffe allotment (includes BLM-managed and privately owned land acres) in each TBM ecological state.

Ecological State	Map units (n)	Acres[1]	Percent of Allotment
A	11	28,505	55.4%
B	2	3,228	6.3%
C: invasive annual grass threat	8	5,272	10.2%
C: Dual threats	12	7,301	14.2%
C: Juniper threat	1	1,243	2.4%
D: Invasive annual grass threat	1	2,377	4.6%
D: Dual threats	3	804	1.6%
D: Juniper threat	2	83	0.2%
E: Dual threats	1	375	0.7%
Other	6	2,297	4.5%

[1] **Excludes intermittent lakes, reservoirs, and playas totaling 2,552 acres.**
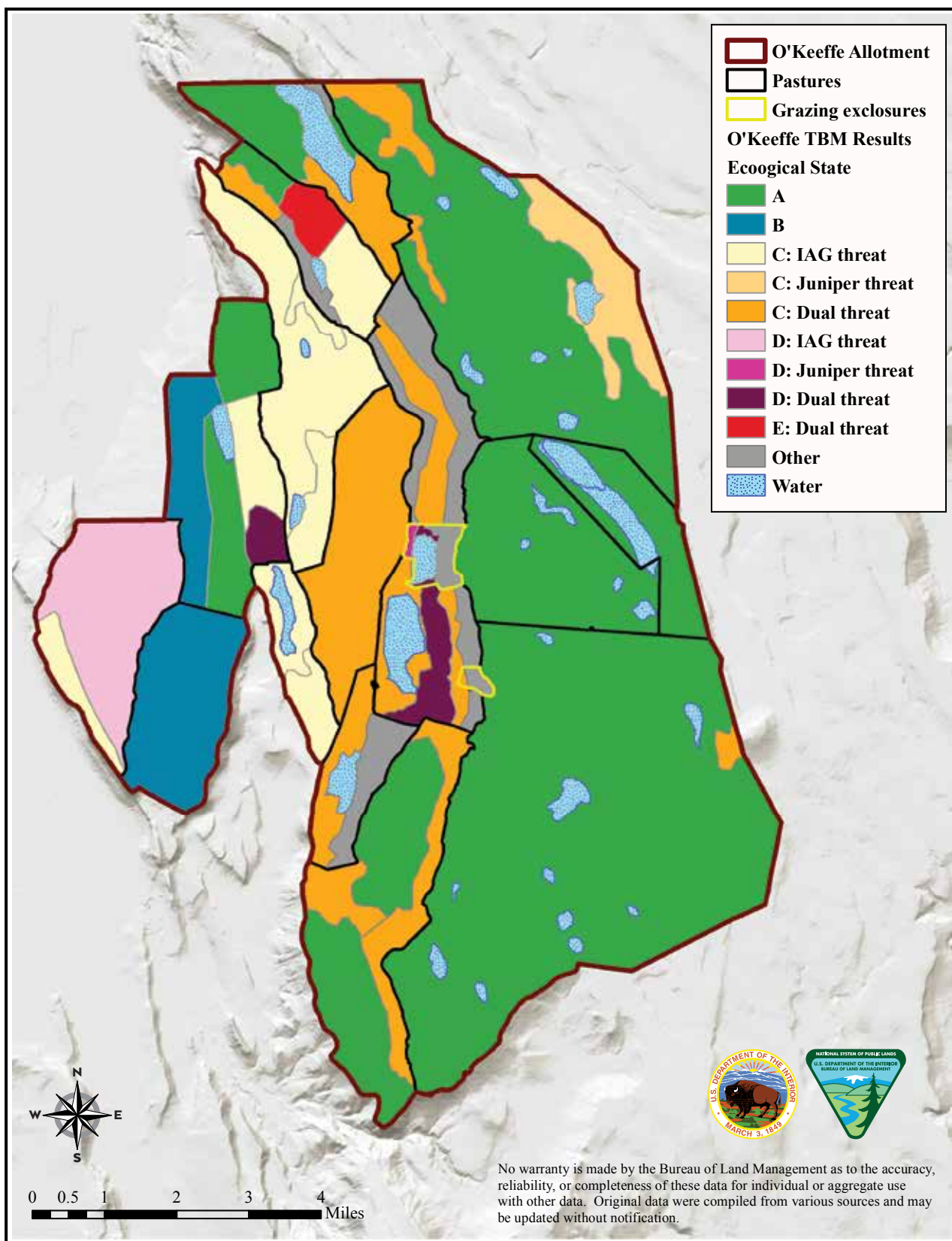
Figure 4. TBM map of the O'Keeffe allotment showing ecological states.

The legend on the map reads:

O'Keeffe Allotment
Pastures
Grazing exclosures
O'Keeffe TBM Results
Ecoogical State
A
B
C: IAG threat
C: Juniper threat
C: Dual threat
D: IAG threat
D: Juniper threat
D: Dual threat
E: Dual threat
Other
Water

No warranty is made by the Bureau of Land Management as to the accuracy, reliability, or completeness of these data for individual or aggregate use with other data. Original data were compiled from various sources and may be updated without notification.

BLM Land Health Assessment Results

In both 1999 and 2017, the O'Keeffe allotment met standards 1, 3, and 5 (other standards are outside the scope of this report). Details of the results for each standard follow.

Standard 1

Results
The allotment continues to meet standard 1. Vegetation composition and soil stability measures from both AIM and long-term trend plots were appropriate for providing adequate infiltration, permeability, moisture storage, and soil stability to protect soil resources. The assessment of the long-term trend plots and AIM plots for the whole allotment included 10 different vegetation communities across all 16 pastures, encompassing 89 percent of the allotment. Cheatgrass dominates 5 percent of the allotment, but the data indicates these sites are stable with adequate vegetation cover to protect the soil from erosion.

Contribution of the TBM to Standard 1
The TBM ecological state map provided an additional line of evidence to assess standard 1 and supported the findings of ESI, trend plot, rangeland health indicator, and AIM data. The TBM map (figure 4) indicates a little over half of the allotment is in state A, including an intact native shrubland appropriate to support watershed function. The interdisciplinary team determined that areas in less desirable condition (C, D, and E) were largely stable and did not cause any pastures to fail standard 1. The addition of spatial TBM maps of vegetation condition covering the entire area complemented the more detailed plot data available at individual AIM and trend plot points, aiding in generalizing across the landscape.

Standard 3

Results
The allotment met standard 3 for ecological processes, except for the 5 percent dominated by cheatgrass because of previous wildfires and unsuccessful reseeding efforts. The intent of current grazing management in these pastures is to reduce cheatgrass cover to promote the return of native vegetation. The other vegetation communities in the allotment are stable as demonstrated by photos and transect data from 21 long-term trend plots that span over 30 years. The data shows the perennial plant cover, bare ground, biological soil crust, seedling establishment, litter, and vegetation composition are within the appropriate range according to the ecological site description. In addition, the team compared data from AIM plots to ecological potential and found it to be within the appropriate range; however, this data has not been collected over multiple years and therefore a trend cannot be established.

Contribution of the TBM to Standard 3
The TBM map aligned very well with the ESI, long-term trend plots, and AIM data, and again provided an additional line of evidence to support the standard 3 determination. As in standard 1, TBMs added value through maps containing continuous spatial coverage across the allotment. The team compared TBM ecological states with seral state distribution from the ESI across the allotment to corroborate the standard determination. The ESI uses a similarity index to determine how closely the current plant community resembles either the potential natural community or some other reference community (Habich 2001), but the level of invasion from annual grasses and juniper is not necessarily captured when assigning a seral state through the ESI process. The TBM provides additional information on the level of invasion by invasive annual grasses and juniper through maps that the team can then use in conjunction with the seral state information produced through the ESI. The TBM framework also allows a simultaneous assessment of current vegetation condition and potential management actions to address ecological threats. The team used ecological threats identified through TBM maps to support management recommendations for areas that were or were not meeting standards as identified through the ESI. The ESI and TBM methodologies worked synergistically to provide a more comprehensive assessment of standard 3.

Standard 5

Results

The LHE found that standard 5 was being met and that the O'Keeffe allotment is "contributing significantly to the amount of quality year-round sage-grouse habitat as a connectivity corridor between Hart Mountain and use areas to the south" (BLM 2017b). Because the eastern half of the allotment was in state A and was meeting standard 5, it provided an important connectivity corridor for sage-grouse seasonal movement.

Sage-Grouse Habitat Assessment Framework Results
The interdisciplinary team determined the Warner-Meinzer second-order HAF analysis area is suitable for sage-grouse because landscapes had large patches of connected sagebrush that allow for bird dispersal and migration, and anthropogenic disturbances that can disrupt dispersal or cause mortality are generally not widespread. We also deemed the Beatys Butte third-order analysis area suitable for sage-grouse, as seasonal habitats were well connected and anthropogenic features that can disrupt seasonal movements or cause mortality were generally absent or not widespread. Sage-grouse telemetry studies in the third-order analysis area indicate sage-grouse are migratory from lek and nesting areas to summer grounds and move considerable distances (>8.7 miles) to winter habitats (Crawford and Carver 2000).

Fourth-order (site-scale) habitat suitability ratings for 49 AIM plots (41 plots applied to two seasons) within seasonal habitats bounded by the Beatys Butte third-order analysis area indicate 64 to 85 percent of sampled upland breeding season habitat, 76 to 100 percent of sampled upland summer habitat, and 89 to 99 percent of sampled winter habitat are suitable for sage-grouse (table 3, figures 5–7). These proportions of suitable seasonal habitat achieved the landscape objective in table 2-2 of the ARMPA (BLM 2015). Moreover, the team rated one-third of the leks marginal or unsuitable (table 3, figure 8), due primarily to juniper encroachment. Fence markers and seasonal road closures mitigated impacts from fences and roads near some active leks. The analysis of upland summer/late brood-rearing habitat indicates that 63 percent of the habitat contained suitable cover of perennial grasses and forbs. However, additional monitoring may be needed to determine if these seasonal habitat indicators are limiting distribution of sage-grouse in the analysis area.

Table 3. Summary of fourth-order Greater Sage-Grouse habitat suitability ratings and proportional area estimates (80% confidence interval) for seasonal habitat types in the Beatys Butte second-order analysis area, Oregon. Leks include occupied, pending, and unoccupied Oregon Department of Fish and Wildlife conservation status.

Seasonal Habitat Type	Number of Leks or Plots			Proportional Area Estimate		
	Suitable	Marginal	Unsuitable	Suitable	Marginal	Unsuitable
Breeding (Lekking)	102 leks	38 leks	8 leks	NA	NA	NA
Breeding (Nesting through Early Brood-Rearing)	28 plots	5 plots	1 plot	74.1% ± 10.4%	19.3% ± 9.0%	6.5% ± 6.5%
Upland Summer and Late Brood-Rearing	6 plots	1 plot	0 plots	88.1% ± 12.6%	11.9% ± 11.9%	0%
Winter	43 plots	2 plots	0 plots	93.9% ± 4.6%	6.1% ± 4.6%	0%
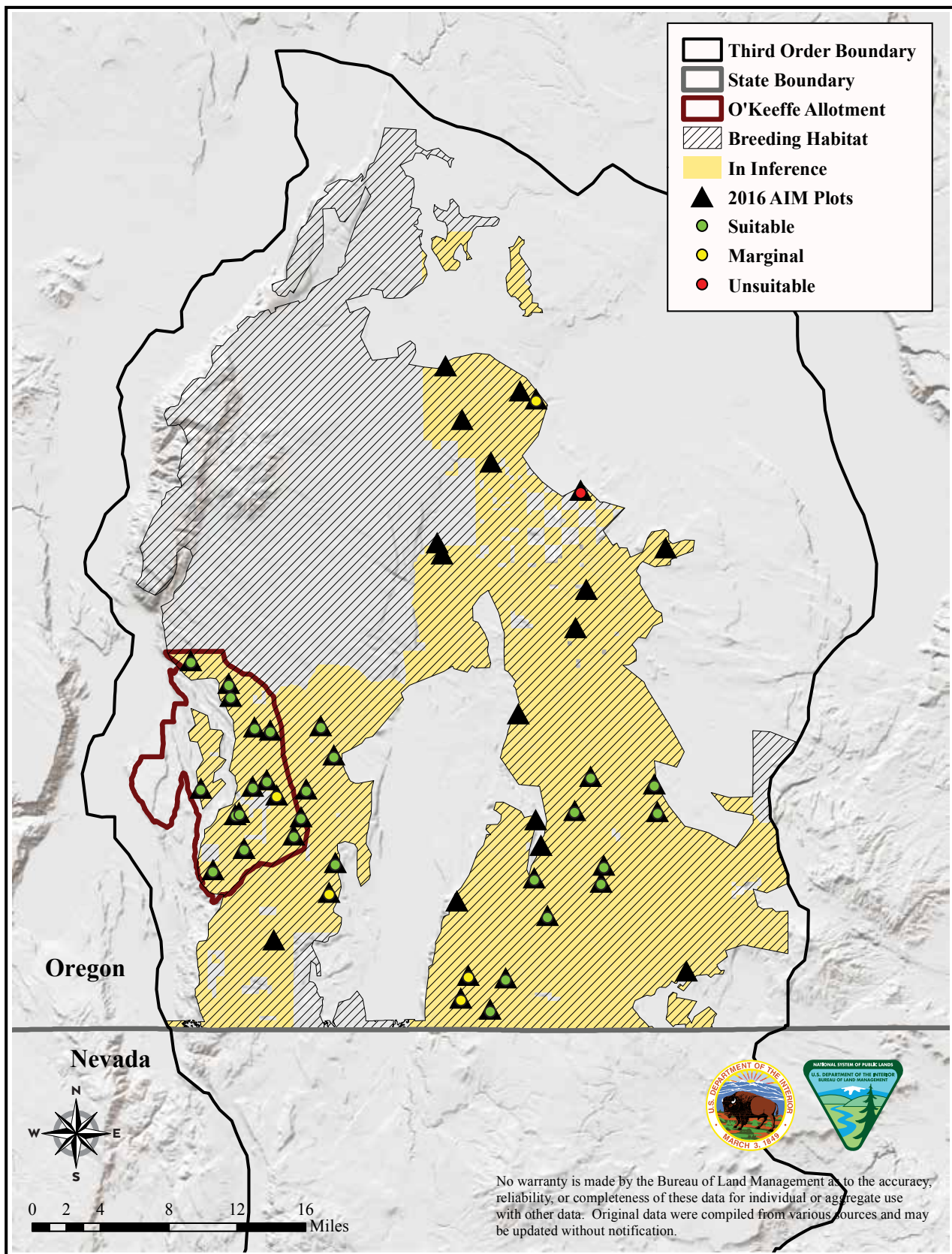
Figure 5. Breeding (nesting and early brood-rearing) seasonal Greater Sage-Grouse habitat within the Oregon portion of the Beatys Butte third-order analysis area. Habitat suitability assessed using the habitat assessment framework (Stiver et al. 2015) at 34 AIM plots on BLM-managed lands within delineated breeding habitat measured between March 1 and June 30, 2016.
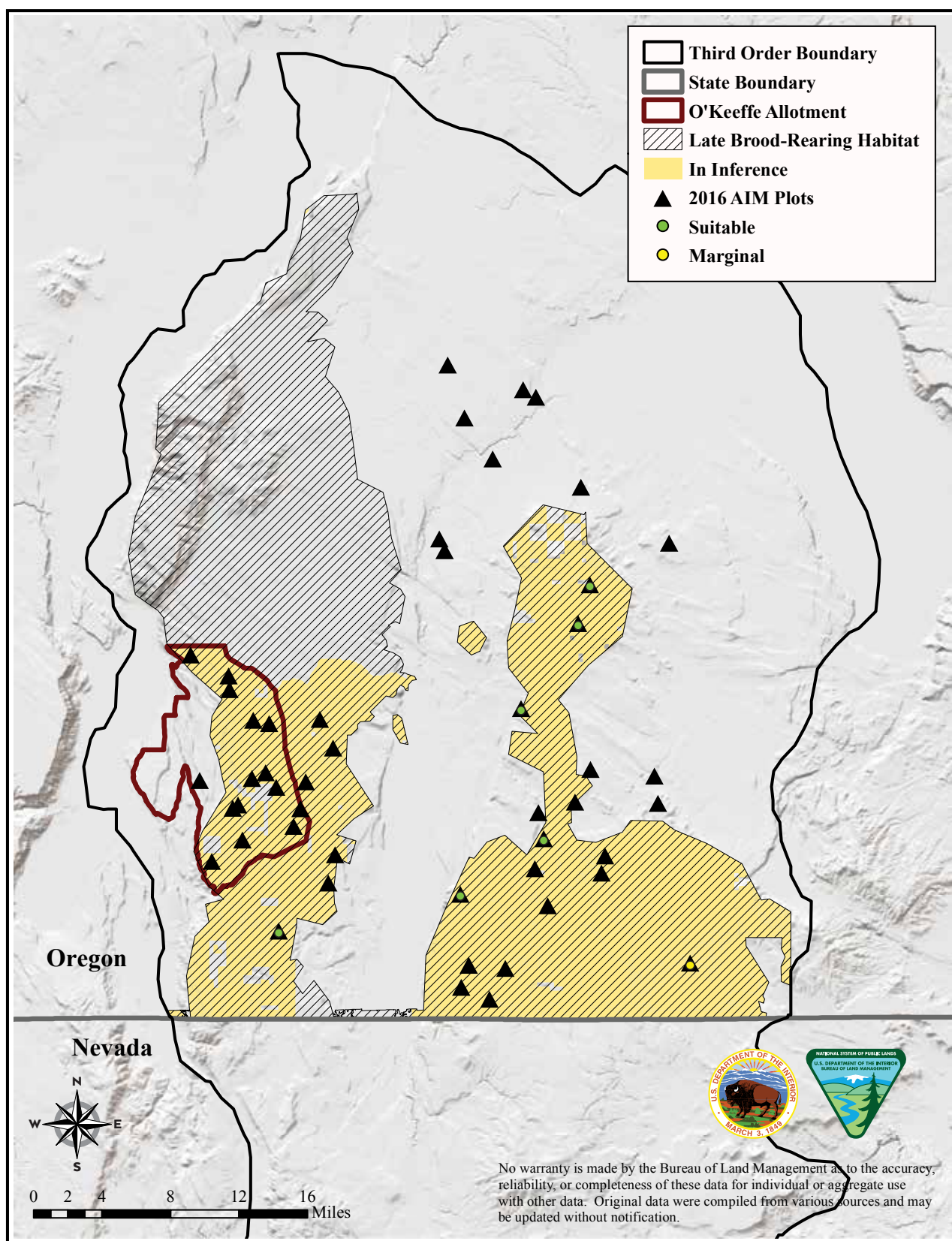
Figure 6. Upland summer and late brood-rearing Greater Sage-Grouse habitat within the Oregon portion of the Beatys Butte third-order analysis area. Habitat suitability assessed using the habitat assessment framework (Stiver et al. 2015) at seven AIM plots on BLM-managed lands within delineated habitat measured between July 1 and October 31, 2016.
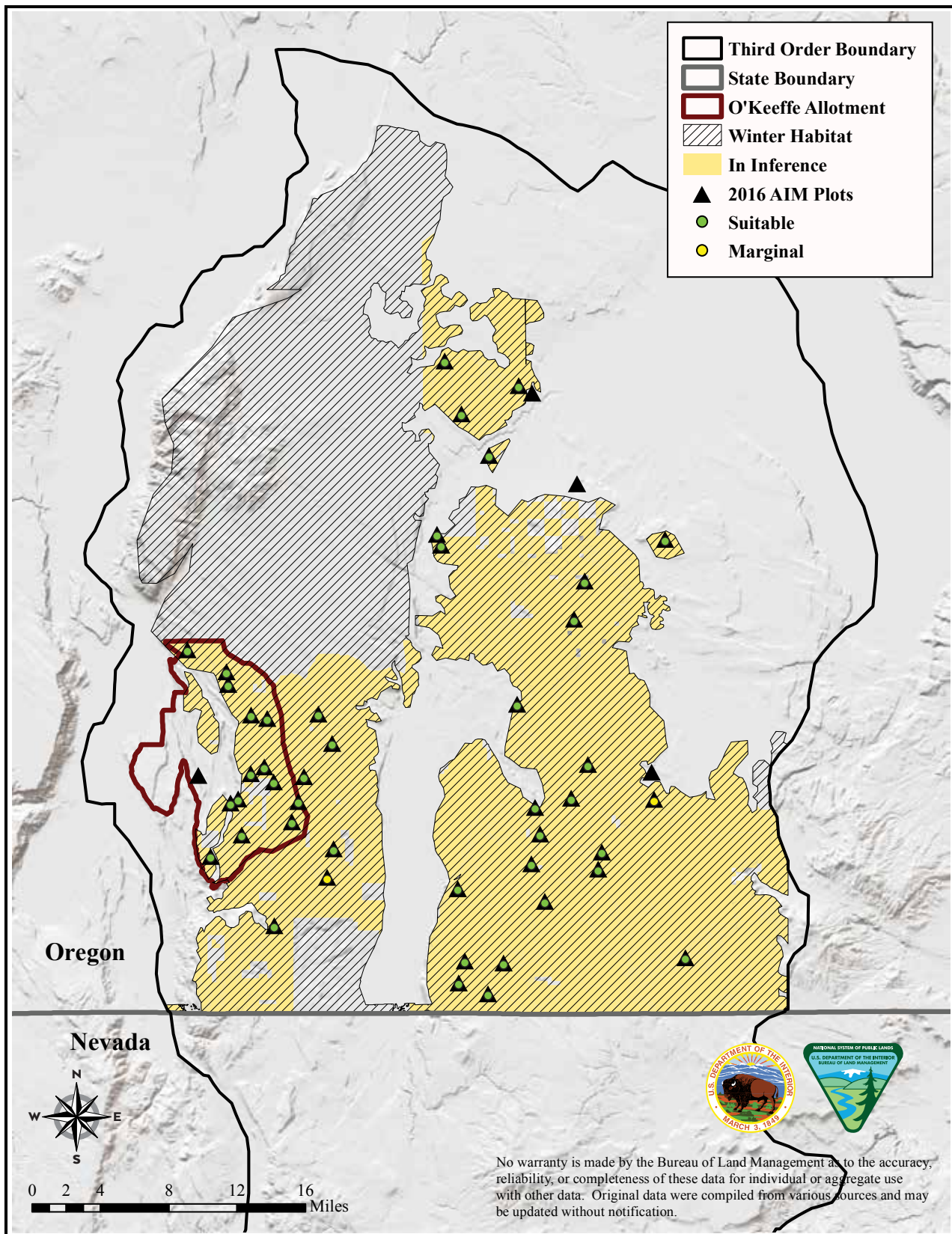
Figure 7. Winter Greater Sage-Grouse habitat within the Oregon portion of the Beatys Butte third-order analysis area. Habitat suitability assessed using the habitat assessment framework (Stiver et al. 2015) at 45 AIM plots on BLM-managed lands within delineated winter habitat measured in 2016.

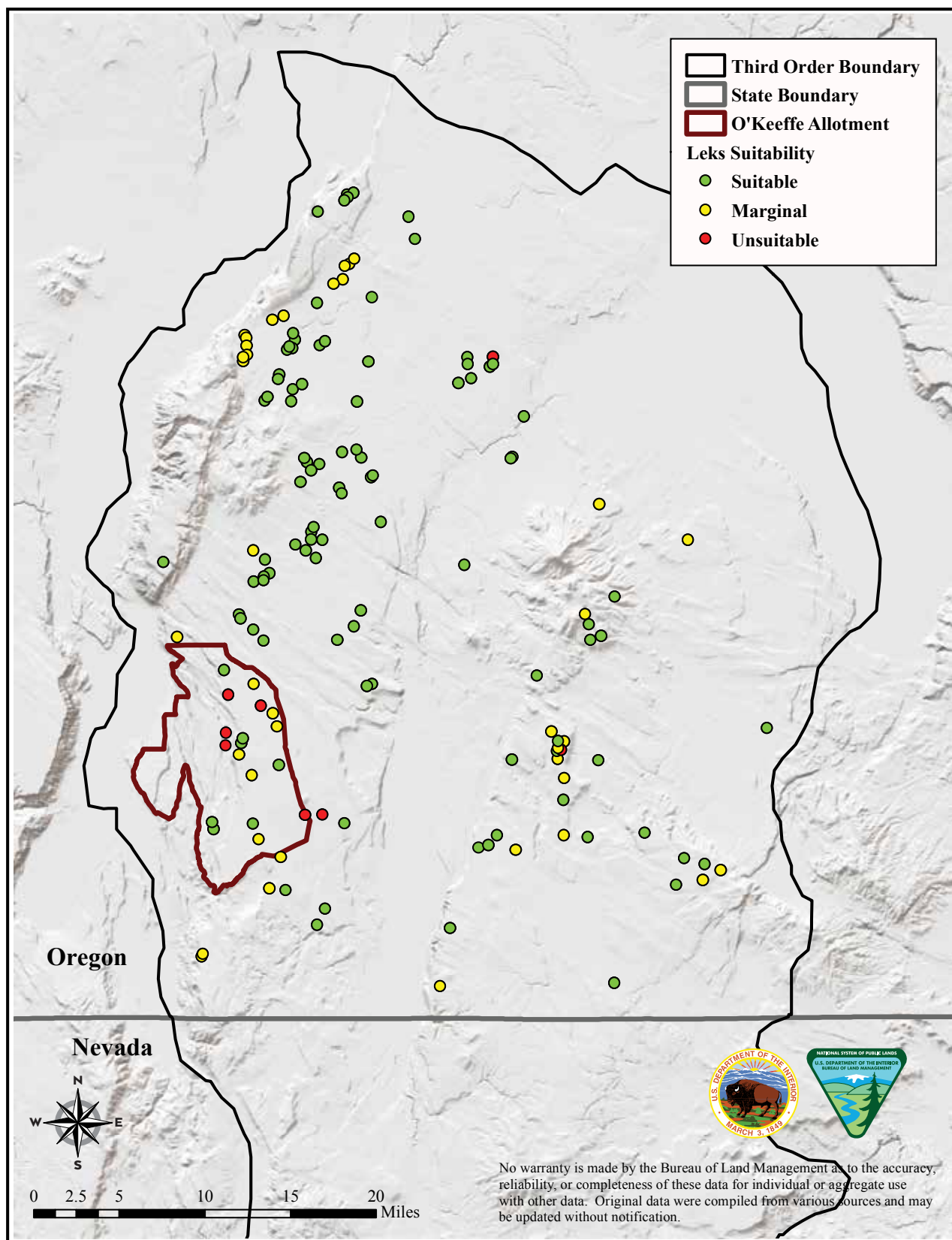**Figure 8.** Greater Sage-Grouse lek suitability within the Oregon portion of the Beatys Butte third-order analysis area. Lek suitability assessed using the habitat assessment framework (Stiver et al. 2015) at 148 leks in 2017.

O'Keeffe Allotment Habitat Assessment Results
For the purposes of this allotment-level LHA, we used fourth-order HAF suitability ratings of plots within the allotment to evaluate standard 5, along with other lines of evidence, including the TBM approach. We found the O'Keeffe allotment to meet standard 5 for sage-grouse. Following are the major findings from the allotment-scale analysis:

- Breeding (lekking) habitat: Seven leks were suitable and 11 leks were marginal (n=6) or unsuitable (n=5), due mainly to juniper encroachment. Unsuitable leks were inactive and impacted by juniper encroachment (figure 8).

- Breeding (nesting/early brood-rearing) habitat (35,815 acres or 66 percent of the allotment): We rated 14 of 15 AIM plots in breeding season habitat as suitable (figure 5). The proportional area estimate of suitable habitat on BLM-managed lands within the allotment was 88 percent ± 13.5 percent suitable and 12 percent ± 12.4 percent marginal. The marginal plot did not have adequate cover of sagebrush, perennial grasses, or forbs. Sagebrush cover exceeded 25 percent in seven plots, and perennial forb cover was less than 6 percent in four plots. However, the team did not rate the overall suitability of a plot based on any one single habitat indicator.

- Upland summer (late brood-rearing) habitat (36,678 acres or 68 percent of allotment): No AIM plots were measured during the brood-rearing/summer season (July 1–October 31) within the O'Keeffe allotment, and therefore no information was available to rate the seasonal habitat. However, most upland summer habitat plots measured in the third-order analysis area were suitable (figure 6), suggesting that summer habitat in the broader landscape is likely to be adequate.

- Winter habitat (33,708 acres or 62 percent of allotment): We rated all 13 AIM plots in winter habitat as suitable (figure 7).

Contribution of the TBM to Standard 5
The HAF served as the primary line of evidence for evaluating standard 5 for sage-grouse. In this pilot study, we used the TBM to help inform the evaluation and provide an additional line of evidence to demonstrate that the allotment was meeting standard 5. Most (74 percent) of the breeding season habitat within the allotment was mapped as state A (table 4), which is the desired ecological state based on the presence of vegetation components that comprise different elements of sage-grouse habitat (Johnson et al. 2019b). In the remaining portion of the allotment, the TBM identified localized areas of threats to sagebrush ecosystem function and sage-grouse habitat. As an ecosystem-based approach that facilitates understanding, mapping, and managing threats (Boyd et al. 2014), the TBM does not provide enough information to complete the HAF on its own. However, the use of both the TBM (also applicable to standards 1 and 3) and the HAF allowed a more comprehensive assessment of standard 5 that included mapping areas impacted by threats to sage-grouse habitat and identifying potential management actions to maintain or promote desired conditions.

Table 4. Proportion of upland sage-grouse seasonal habitat type within the O'Keeffe allotment classified by TBM ecological state.

Seasonal Habitat Type	TBM Ecological State Estimates							
	A	C: Juniper threat	C: Dual threats	C: Invasive annual grass threat	D: Juniper threat	D: Dual threats	E: Dual threats	Nonhabitat
Breeding (Lekking)	83%		6%					
Breeding (Nesting through Early Brood-Rearing)	74%	3%	13%	3%	<1%	<1%	<1%	<1%
Upland Summer and Late Brood-Rearing	73%	3%	12%	<1%	<1%	1%	<1%	4%
Winter	77%	4%	8%	4%			<1%	<1%

During the application of the TBM process, we identified secondary threats to sage-grouse habitat for each polygon while completing the Upland Ecological State Documentation Form. Threats to sage-grouse habitat that were present within the O'Keeffe allotment include drought and climate change, infrastructure to support livestock management (primarily unmarked fences near leks), invasive vegetation, predation (primarily issues surrounding predator subsidies and perching related to structures), recreation, juniper expansion, West Nile virus, and wildfire (BLM 2017b).

Next Steps in the Land Health Process

We found that the O'Keeffe allotment met all upland standards. This report focuses on the steps of the land health assessment and evaluation process; however, following the land health evaluation, the BLM will undergo the following steps, some of which may be informed by the TBM.

Identify Causal Factors

Following the LHE, if the allotment is not meeting standards, the BLM will determine which existing management activities are significant causal factors. To ensure conformance with subpart 4180 of the federal grazing regulations, a determination also documents the authorized officer's finding that grazing management practices or levels of grazing use on public lands either are or are not significant factors for failing to achieve the standards and conform to the guidelines for livestock grazing management within a specified geographic area. Sites within the assessment area where resource problems currently exist or that are potentially at risk of degradation are identified in the determination, and the TBM could be used for mapping and communicating these ecosystem threats and identifying opportunities for proactive management actions to address those threats.

Identify Management Recommendations

The LHE identifies management needs based on the findings in the LHA. For the O'Keeffe LHA, the interdisciplinary team used the TBM ecological state and distribution to make recommendations for managing juniper invasion and invasive annual grass threats.

Implement Management Recommendations

The next step of implementing land health recommendations is to develop alternative actions for National Environmental Policy Act (NEPA) analysis. We did not include this step as part of the pilot study, but we recognized the utility of the TBM to facilitate communication with stakeholders through maps and easily interpretable ecological state descriptions.

Monitor Progress (Adaptive Management)

The LHE represents a point in time, but there is a need for ongoing monitoring of condition and progress toward maintaining or improving condition. The BLM collects AIM data over a 5-year window that will be helpful to establish trends, and in many areas, existing trend plots can also provide information about change over time. Repeating habitat assessments at the appropriate scale(s) with new data could inform adaptive management. Other methods, such as the HAF and the TBM, provide a snapshot in time. The TBM identifies apparent trend; however, it is not a substitute for quantitative monitoring. The TBM could identify areas that warrant further monitoring (e.g., areas with unclear apparent trend), and newer remotely sensed products may aid in trend analysis (Jones et al. 2018, Rigge et al. 2019).

Conclusions

This pilot study originated in 2016 with a narrow focus on individual tools—AIM, HAF, and TBM—and the application and use of these tools in a BLM LHA and LHE. We implemented the tools in isolation without initial integration, which required additional time and effort, and did not allow for a comprehensive look at how integration of tools could gain efficiencies. Future efforts should focus on TBM mapping in conjunction with the LHA and may serve to streamline how the BLM identifies and responds to ecological threats, both within the allotment and on the landscape. In addition, the Beatys Butte area contains some of the highest quality sage-grouse habitat in Oregon, and using the TBM in other landscapes would help clarify the role of the TBM in areas that fail standards or where management intervention is needed.

The TBM approach focuses on broad functional groups to assess ecosystem function, offering generalized information and mapping it continuously across the whole landscape. This approach complements the plot-based approaches more commonly used in the LHA, which involve collecting more detailed information at distinct points. The pilot study demonstrated the utility of TBM maps alongside point-based estimates of vegetation cover, soil stability, and other measures of function as another line of evidence to support the evaluation of standards 1, 3, and 5.

TBM states do not necessarily have a direct correlation to indicators used in land health standards or site potential, and do not measure all key indicators of rangeland health. In fact, it is possible for invaded or threatened states to meet some standards. Where determination of site potential is critical to assessing compliance, additional data such as ecological site descriptions will be needed to supplement the TBM. The TBM also does not incorporate the requisite indicators to rate seasonal habitat suitability for sage-grouse.

The primary areas where the TBM approach may add value in the BLM LHE are:

- **Mapping threats on the landscape.** TBM maps provide a spatial depiction of primary ecosystem threats on the landscape and can also identify secondary threats to sage-grouse such as unmarked fences and avian predator perches.

- **Providing a communication tool to engage stakeholders.** The TBM framework intentionally simplifies complex landscapes to communicate the primary threats and conservation measures needed to address those threats. Maps can be effective tools for communication with stakeholders and help to generate early buy-in for future management such as restoration projects. The TBM mapping process can encourage non-value-based discussion surrounding ecological conditions and help build a common understanding of ecosystem threats.

- **Linking threats present to conservation measures.** TBMs directly link threats to potential conservation measures on the landscape (Johnson et al. 2019b), which may be helpful in linking the LHA to management interventions necessary to meet standards in the LHE.

- **Prioritizing areas for monitoring or management.** TBMs could provide a framework to streamline additional sampling in areas where the BLM needs more information to support the HAF rating or other information needed to address rangeland health standards. The TBM maps can also facilitate conversations about how and where to prioritize management actions across the landscape to address the most important needs.

- **Improving efficiency in the LHE.** TBMs provide an additional line of evidence and may streamline assessments of standards 1 and 3 by serving as a simpler starting point for stratification. For standard 5, TBMs can supplement vegetation condition information where plot data is lacking. The TBM process of identifying and mapping threats lends itself to cross-program work and improved communication among the BLM's resource staff, which could ultimately lead to efficiencies in implementing management decisions. However, determining if efficiencies can be gained in practice will require further implementation.

- **Facilitating consistent assessment across public and private lands.** TBMs could provide a consistent approach to assessing current vegetation conditions across all lands, which may be beneficial at a variety of scales, from ranch planning to watershed planning.

- **Facilitating landscape-scale assessment.** Newer tools such as TBMs and others also provide promise in aiding the LHE in a broader landscape context. Both the 1999 and 2017 LHE for the O'Keeffe allotment focused on the allotment area because it was a priority allotment for permit renewal, which is often the case. However, the BLM (2001) directs field offices to use fifth-level watershed boundaries when conducting LHAs, except when compelling issues dictate that an administrative or other ecosystem-based boundary takes precedence. Newer tools and frameworks such as TBMs may be helpful in facilitating this broader, landscape-scale approach to assessments as originally intended. Although not included in this pilot study, aggregation of AIM data to the landscape scale could provide context for upland vegetation and soil indicators relative to large-scale planning efforts or project proposals. Additionally, concepts such as disturbance response groups (Stringham et al. 2016) may provide opportunities to aggregate and map ecological site potential across broader landscapes, aiding in evaluating condition relative to site potential at a broader scale. Since the pilot study began, there has also been a large increase in the availability of remote sensing map products to estimate continuous vegetation cover across large landscapes (Henderson et al. 2019, Jones et al. 2018, Sant et al. 2014, Xian et al. 2015).[1] TBM maps have been produced to cover all rangelands in Oregon[2] and can provide information on broad-scale threats across private and public land ownership boundaries, scaling from individual properties or allotments to much larger areas such as HAF second- or third-order boundaries. These tools and products show promise for evaluating land health at broader scales with multiple lines of evidence, and work is ongoing with partners in the state to leverage these tools in the BLM LHA process.

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[1] For a list of rangeland map products in Oregon as of 2019, see https://oregonexplorer.info/content/rangeland-vegetation-map-products-oregon?topic=203&ptopic=179.

[2] TBM maps across all rangelands in Oregon are available on the SageCon Landscape Planning Tool, accessible at https://tools.oregonexplorer.info/OE_HtmlViewer/index.html?viewer=sagegrouse.

Literature Cited

BLM (Bureau of Land Management). 1997. Standards for rangeland health and guidelines for livestock grazing management for public lands administered by the Bureau of Land Management in the states of Oregon and Washington. Bureau of Land Management, Oregon-Washington State Office, Portland, OR. 19 pp.

BLM (Bureau of Land Management). 1999. Sampling vegetation attributes. Interagency technical reference No. 1734-4. U.S. Department of the Interior, Bureau of Land Management, National Applied Resource Sciences Center, Denver, CO.

BLM (Bureau of Land Management). 2001. Rangeland health standards. Handbook 4180-1. Bureau of Land Management, Washington, DC. 51 pp.

BLM (Bureau of Land Management). 2015. Oregon greater sage-grouse approved resource management plan amendment. Attachment 3. U.S. Department of the Interior, Oregon/Washington State Office, Portland, OR. 252 pp.

BLM (Bureau of Land Management). 2017a. Bureau of Land Management greater sage-grouse habitat assessment summary report for the Beatys Butte fine-scale assessment area, southern Oregon and northern Nevada. Unpublished report. Bureau of Land Management, Lakeview District Office, Lakeview, OR.

BLM (Bureau of Land Management). 2017b. Standards for land health evaluation and guidelines for livestock grazing management for public lands in Oregon and Washington: Update for O'Keeffe (#00216). Unpublished report. Bureau of Land Management, Lakeview District Office, Lakeview, OR.

BLM (Bureau of Land Management). 2018. Gunnison and greater sage-grouse (including bi-state distinct population segment) habitat assessment policy. Instruction Memorandum 2018-021. Bureau of Land Management, Washington DC.

Crawford, J.A. and L.A. Carver. 2000. Habitat use by sage grouse on the Beatys Butte allotment. Final report. Oregon State University. Corvallis, OR.

Habich, E.F. 2001. Ecological site inventory. Technical reference 1734-7. BLM/ST/ST-01/003+1734. Bureau of Land Management, Denver, CO. 112 pp.

Henderson, E. 2016. Greater sage-grouse seasonal habitat mapping in southwest Oregon. Unpublished report. Institute for Natural Resources, Oregon State University. 20 pp.

Henderson, E.B., D.M. Bell, and M.J. Gregory. 2019. Vegetation mapping to support greater sage-grouse habitat monitoring and management: Multi- or univariate approach? Ecosphere 10(8):e02838. https://doi.org/10.1002/ecs2.2838.

Herrick H.E., J.W. VanZee, S.E. McCord, E.M. Courtright, J.W. Karl, and L.M. Burkett. 2017. The monitoring manual for grassland, shrubland, and savanna ecosystems. Second edition. Volume 1: Core methods. U.S. Department of Agriculture, Agricultural Research Service, Jornada Experimental Range, Las Cruces, NM. 77 pp.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61(1):65-71.

Johnson, D., M. Cahill, C. Boyd, V. Schroeder, L. Foster, A. Sitz, J. Kerby, T. Svejcar, and J. Cupples. 2019a. Threat-based land management in the northern Great Basin: A field guide. PNW 723. Oregon State University Extension Service, Corvallis, OR. https://catalog.extension. oregonstate.edu/pnw723.

Johnson, D., M. Cahill, C. Boyd, V. Schroeder, L. Foster, A. Sitz, J. Kerby, T. Svejcar, and J. Cupples. 2019b. Threat-based land management in the northern Great Basin: A manager's guide. PNW 722. Oregon State University Extension Service, Corvallis, OR. https://catalog.extension. oregonstate.edu/pnw722.

Jones, M.O., B.W. Allred, D.E. Naugle, J.D. Maestas, P. Donnelly, L.J. Metz, J. Karl, R. Smith, B. Bestelmeyer, C. Boyd, J.D. Kerby, and J.D. McIver. 2018. Innovation in rangeland monitoring: Annual, 30 m, plant functional type percent cover maps for U.S. rangelands, 1984–2017. Ecosphere 9(9):e02430. https://doi.org/10.1002/ ecs2.2430.

Kachergis, E., N. Lepak, M. Karl, S. Miller, and Z. Davidson. 2020. Guide to using AIM and LMF data in land health evaluations and authorizations of permitted uses. Technical Note 453. U.S. Department of the Interior, Bureau of Land Management, National Operations Center, Denver, CO.

Oyarzun, M. 2017. Greater sage-grouse seasonal habitat shapefiles. Bureau of Land Management, Northern California District Office, Redding, CA.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health. Technical Reference 1734-6. Version 4. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Rigge, M., H. Shi, C. Homer, P. Danielson, and B. Granneman. 2019. Long-term trajectories of fractional component change in the northern Great Basin, USA. Ecosphere 10(6):e02762. https://doi.org/10.1002/ecs2.2762.

SageCon (Sage-Grouse Conservation Partnership). 2015. The Oregon sage-grouse action plan. Governor's Natural Resources Office. Salem, Oregon. 221 pp. plus appendices. https:// oregonexplorer.info/content/oregon-sage-grouse-action-plan?topic=203&ptopic=179.

Sant, E.D., G.E. Simonds, R.D. Ramsey, and R.T. Larsen. 2014. Assessment of sagebrush cover using remote sensing at multiple spatial and temporal scales. Ecological Indicators 43:297–305.

Stiver, S.J., E.T. Rinkes, D.E. Naugle, P.D. Makela, D.A. Nance, and J.W. Karl, eds. 2015. Sage-grouse habitat assessment framework: A multiscale assessment tool. Technical reference 6710-1. Bureau of Land Management and Western Association of Fish and Wildlife Agencies, Denver, CO.

Stringham, T.K, P. Novak-Echenique, D.K. Snyder, S. Peterson, K.A. Snyder. 2016. Disturbance response grouping of ecological sites increases utility of ecological sites and state-and-transition models for landscape scale planning in the Great Basin. Rangelands 38(6):371-378.

Toevs, G.R., J.J. Taylor, C.S. Spurrier, W.C. MacKinnon, and M.R. Bobo. 2011. Bureau of Land Management Assessment, Inventory, and Monitoring Strategy for Integrated Renewable Resources Management. Bureau of Land Management, National Operations Center, Denver, CO.

USFWS (U.S. Fish and Wildlife Service). 2013. Greater sage-grouse (*Centrocercus urophasianus*) conservation objectives: Final report. U.S. Fish and Wildlife Service, Denver, CO.

USFWS (U.S. Fish and Wildlife Service). 2014. Greater sage-grouse programmatic candidate conservation agreement with assurances for private rangelands in Harney County, Oregon between the Harney Soil and Water Conservation District and the United States Fish and Wildlife Service. Portland, OR.

USFWS (U.S. Fish and Wildlife Service). 2017. Threat based ecological state and transition model habitat assessment approach to grazing permit renewals in the Great Basin. Unpublished report prepared for the Regional Directors of U.S. Fish and Wildlife Service Regions 1, 6, and 8. Portland, OR.

Xian, G., C. Homer, M. Rigge, H. Shi, and D. Meyer. 2015. Characterization of shrubland ecosystem components as continuous fields in the northwest United States. Remote Sensing of Environment 168:286-300.