Ecosystem Change in the Blue Mountains Ecoregion: Exotic Invaders, Shifts in Fuel Structure, and Management Implications, Project #: 16-1-01-21

JFSP Funding Opportunity, A-FON0016-0001, Task 1 – Implications of Changing Ecosystems
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Co-Investigators: Dr. Harold Zald (Oregon State University, OSU), Dr. Meg Krawchuk (OSU), Dr. Nicole Valliant (PNW), Dr. John Kim (PNW) and Bridgett Naylor (PNW) (see Co-PI CV's for details).

I. Overview

Exotic plant invasions are a growing challenge to the management of native biodiversity, ecosystem functioning, and fuels and fire management. The effects of exotic invaders are particularly dramatic when they alter disturbance regimes beyond the range of variation to which native species are adapted, resulting in community shifts and ecosystem transformations (D'Antonio and Vitousek 1992; Mack and D'Antonio 1998). Exotic annual grasses that alter fire regimes are recognized as some of the most important ecosystem-altering species on the planet (Brooks et al. 2004). Grasses such as *Bromus tectorum* (cheatgrass) and *Taeniatherum caput-medusae* (medusahead) are negatively impacting millions of hectares across the Great Basin by fundamentally altering the ecosystems in which they invade (DiTomaso 2000). A similar threat is developing in the forestlands of the interior Pacific Northwest region with a relatively new invasive annual grass, *Ventenata dubia* (ventenata, North Africa grass). Ventenata thrives at higher elevations than does cheatgrass, where it threatens native forest biodiversity and is creating ecosystem-level changes. Recent engagement with managers has revealed that ventenata is a primary species of concern in many areas of the Blue Mountains Ecoregion (BME) of the Pacific Northwest (Fig. 1).

Forest and fire managers lack critical information as to how ventenata is altering fuels and fire regimes, the implications this has for fuel treatment programs, and which post-fire management strategies may be effective in mitigating the impacts of ventenata in the context of changing fire regimes and climate.

Of particular concern is ventenata's ability to create novel landscape conditions and alter fire behavior. Forestland managers note that ventenata is a "game changer" largely because of the species' ecosystem-level transformation potential. Several large wildfires in 2015 burned over 300,000 acres of forests and rangelands in the BME (Fig. 1). Fire and fuels resource managers working these fires expressed concern regarding novel fire behavior, particularly in open meadows and scablands interspersed within the forest matrix. These open areas occur throughout the BME and are tactically used as wildland fire breaks and firefighter safety zones because fire does not traditionally carry through them well due to the presence of small statured species and interspaces of shallow, gravelly/rocky soils (Johnson and Swanson 2005), resulting in low fuel connectivity (Fig. 2). The spatial arrangement of fuels across the landscape is a major driver of wildland fire behavior, and ventenata invasion has dramatically changed these areas, creating flashy fuel beds prone to fast moving fire. In the 2015 fires, firefighters witnessed rapid fire spread fueled by this dry grass (Hallmark and Romero 2015). The exotic annual grass-fire cycle is recognized for cheatgrass in the Great Basin (DOI 2015). Ventenata poses a similar, although poorly understood, threat to the wildlands of the BME.

We are proposing a landscape scale research project focused on the Blue Mountain Ecoregion to examine the extent of ventenata invasion and associated ecosystem change. We will examine how fuels, fire regimes, and fire effects might shift across the region, and how these changes might affect

management. We will depict alternative future scenarios of ecosystem change associated with future climate change and management actions.

- **Project Justification and Expected Benefits**

Ventenata was first reported in North America in 1952 in Washington (Old and Callihan 1987). The species has since spread to seven western states (CA, OR, ID, WY, WA, UT, MT). Ventenata is an increasing concern for both public and private land managers for a variety of reasons. Similar to other exotic invasive annual grasses it is aggressive and can dominate large areas across the landscape. The plant dries earlier in the summer than native species, but later than other exotic annual grasses, and remains highly flammable throughout the fire season creating dangerous conditions on the ground. From monitoring plots and remotely sensed data, land managers have noted that ventenata has increased and spread over the past decade in mountain meadows and scablands of the BME, outcompeting native bunchgrasses and other exotic annual grass (Noone et al. 2013; McKay et al. in review; Sabine-Mellmann Brown, personal communication; Starkey Experimental Forest and Range, unpublished data).

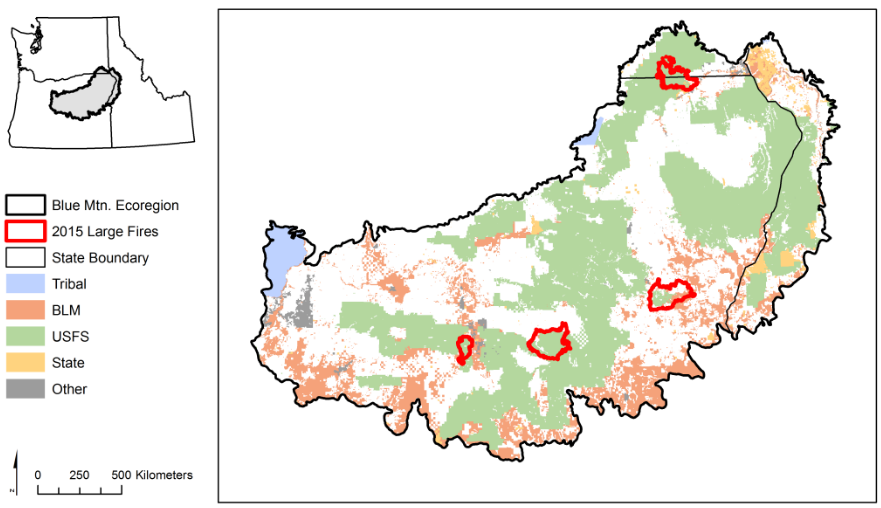

Fig. 1—Blue Mountains Ecoregion (Omernik 1987, US EPA 2013), which spans three states (OR, WA, ID) of the Pacific Northwest, four national forests, and other land ownerships. Four large fires burned in the region in 2015, shown in red.

While current ecosystem level changes due to ventenata invasion are being realized, further changes are anticipated with predicted climate change. A recent assessment of potential climate change effects on upland vegetation in the BME suggested that the likelihood of forest, woodlands and shrublands being invaded by exotic annual grasses in a warmer climate will increase because of more disturbance (fire, insect and disease outbreaks, fuel treatments), effects of warming on species distributions, enhanced competitiveness of exotic plants from elevated carbon dioxide, and increased stress to native species (Kerns et al., in press).

Although the spread of ventenata has been rapid in the last decade, very little is known about the species' basic ecology (Wallace et al. 2015). Even less is known about the species response to disturbance - fire in particular - and how its abundance can be influenced through land-use and management activities (Northam and Callihan 1994; Scheinost et al. 2008; Johnson et al. 2013). To address this significant knowledge gap, we are proposing landscape scale research focused on the BME to examine the extent of ventenata invasion and associated ecosystem change. Data from our study will help land mangers develop restoration and rehabilitation approaches, and determine what strategies are most likely to be successful at containing ventenata in the longterm. Understanding drivers of current and potential future ventenata extent across the landscape can be important for future management actions, in particular future fuels and fire management.

Fig. 2. Example of an open area within a forested matrix that has only minor ventenata (left). Scattered low statured native species, bare soil and cryptograms make these areas resistant to fire spread. The area on the right has major infilling of ventenata, creating fuel connectivity for fires.

This research emerged directly from manager engagement. The Hallmark and Romero brief about the ventenata fuel issue for the 2015 fires was sent to PNW and Kerns with the goal of engaging research action. Before preparing this proposal, we held discussions with USFS and BLM fire, fuel, and vegetation managers, local and regional USFS staff, and the Blue Mountain and central Oregon USFS zoned ecologists. Our goal was to engage managers and understand their issues. There is strong local and regional support for this work across multiple program areas (see Letters of Support). This proposal is supported by the USFS Region 6 (Pacific Northwest) Regional Forester Jim Pena. Mr. Pena wrote this letter based on support from the Ecology (Tom DeMeo), Botany (Mark Skinner), Range (Thomas Hilken) and Fire and Fuel (Kevin Martin) programs. The research is also supported by Mike Haske, the BLM Oregon State Office Division Chief for Natural Resources. All four USFS forest supervisors in the BME also support the work.

- **Project Objectives**

  The objectives of the research are multi-phased and include:

  1. Determine the state of the ventenata invasion in the BME and examine how the invasion has changed through time and what environmental (climate, soil, light) and disturbance (fire and grazing) factors influence and/or exacerbate populations. Develop a spatially explicit map of ventenata distribution and spread, and predictive model habitat suitability in the BME. Research questions:
     - *Where is ventenata increasing across the landscape? What environmental factors are related to presence? What type of disturbances and management practices are exacerbating populations?*
  2. Determine how different future climate change scenarios may alter the habitat suitability and potential distribution of ventenata in the BME. Research question:
     - *How might climate change alter the ventenata invasion?*
  3. Examine and describe ventenata dynamics in scablands and open areas.

3a. Examine the post-fire response of ventenata to recent wildfires. Research questions:

- *Does fire exacerbate ventenata populations? Is the response related to fire severity, pre-fire invasion levels, or environmental conditions*?

3b. Characterize ventenata populations along open area/forested edges in invaded areas that have not burned. Research questions:

- *What do open area/forested edges look like with respect to spread of ventenata into the forested understory? Does ventenata invasion result in fuel connectivity at these edges?*

4. Estimate potential shifts in fuels and fire regimes by developing scenarios to examine how the ventenata invasion might change fuels, fire behavior, burn probabilities, fire size and fire effects across large landscapes now and into the future using several operational climate change scenarios. Research questions:
    - *How might fuels, fire regimes, and fire effects shift across the region when the ventenata invasion reaches full potential (e.g. all available habitat invaded)? How might fuels, fire regimes, and fire effects shift across the region under future climate change?*

o **Relation to Task Statement Research Questions**

Fig. 3 links the four objectives to the task statements in a conceptual model, and provides an overview of the linkages between the objectives. Research outcomes from all four objectives will be interpreted and synthesized based on the following two over-arching questions: *What are the implications for fuels treatment or other management programs? What are the implications for post-fire restoration and rehabilitation?*

- Changing fuels and fire regimes – Our research will answer questions about how fuels, fire regimes, and fire effects may shift across the Blue Mountain Ecoregion due to the ventenata invasion now, and into the future, and how these changes might affect fuels and fire management.
- Implications for management programs – We will examine how fire, grazing and fuel treatments (thinning and burning) might be exacerbating ventenata populations, and what the implications are for fuels treatments or grazing management. We will also explore whether fire (prescribed or wild) is exacerbating ventenata and the implications for post-fire restoration and rehabilitation, and which post-fire restoration and rehabilitation strategies are most likely to be successful in the long-term.

The research we are proposing is operational in nature because we are developing scenarios for a real landscape with targeted management concerns expressed from engagement with managers. Essentially each objective includes both science assessment (particularly Objectives 1-3) and integration and interpretation of this information in an operational scenario analysis depicting managers' ability to meet land and resource management objectives (particularly Objective 4).

II. Methods

o **Study Site**

The BME extends from the Ochoco Mountains in central Oregon to Hells Canyon of the Snake River in extreme northeastern Oregon and adjacent Idaho, and then north to the deeply carved canyons and basalt rimrock of southeastern Washington (Fig. 1). Landownership includes four national forests (Ochoco, Malheur, Umatilla, Wallowa-Whitman), BLM, state and private, and tribal lands. Powell (2012) defined six vegetation zones within the Ecoregion, which range from low elevation grasslands to high elevation alpine areas. The lower montane zone, contains dry conifer forests characterized by ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and grand fir (*Abies grandis*). The upper montane zone includes moist forests characterized by Douglas-fir, grand fir, and subalpine fir

(*Abies lasiocarpa*). High elevations support a subalpine zone with Engelmann spruce (*Picea engelmannii*), subalpine fir, and whitebark pine (*Pinus albicaulis*) or an alpine zone near mountain summits where trees are absent. In the past, dry conifer forests generally supported frequent fire regimes, ~13-35 year return interval, with more frequent regimes in the southern part of the ecoregion (Heyerdahl et al.2001). For dry, frequent-fire forests, present-day stand structure, species composition, fuel accumulation and associated risk of severe fires, and insect and disease outbreaks are generally regarded as historically uncharacteristic and undesirable. Moist upland forests generally support mixed-severity fire regimes, but low-severity and high-severity regimes also occur (Stine et al. 2014).

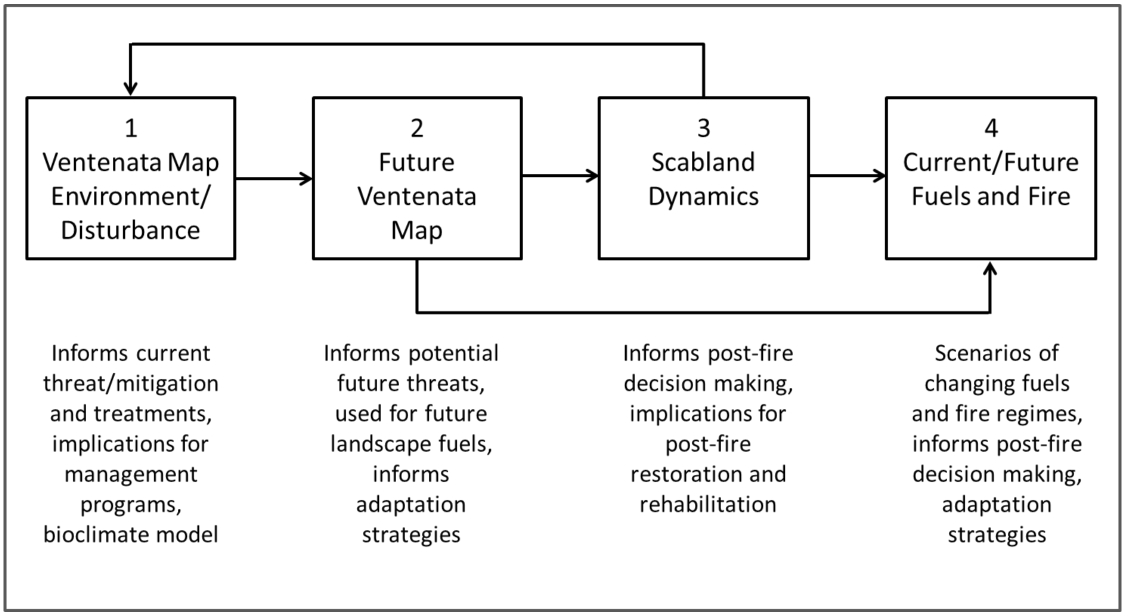

Fig. 3. Schematic depicting links and feedbacks between the four objectives and relationships to the task statements in a conceptual model.

- **Specific Methods by Objective**

Objectives 1 and 2: Map the current extent of invasion and spread, examine interactions with management actions, and project potential change due to future climate. We will map ventenata distribution by developing spatially explicit predictive models that relate georeferenced field plot data (USFS ecology, monitoring plots, NRCS plots, research plots, new field data) of ventenata occurrence and abundance to satellite imagery and existing ancillary geospatial data characterizing biophysical variables (gridded climate, topography, and soils). Compared to native vegetation, exotic grasses have an earlier spring green up and subsequent drying and browning, resulting in a distinct seasonal spectral signature that can be detected and mapped with multi-temporal satellite imagery (Clinton et al. 2009; Noone et al. 2013; Boyte et al. 2015). MODIS imagery provides the dense temporal time series to characterize seasonal spectral changes, but its coarse resolution (250-1000m pixel, depending on specific image product) poses problems for characterizing finer grain vegetation mosaics such as scabland patches. Landsat imagery has a finer resolution (30 m pixel) compatible with characterizing vegetation patterns, but its longer remeasurement period (~16 days) has limitations for characterizing seasonal spectral patterns. We will address these spatiotemporal tradeoffs by blending Landsat and MODIS imagery using the spatial and temporal adaptive reflectance fusion model (STARFM, Gao et al. 2006), from which high resolution seasonal phenology metrics of surface reflectance and vegetation indices will be calculated. Spatial predictions (maps) of ventenata occurrence and abundance will be generated by related plot-level ventenata observations with the blended satellite imagery and gridded biophysical variables using the MAXENT bioclimatic envelope approach (Bradley et al. 2010). Ventenata distributions will be mapped for both 2014 and 2004, providing spatial information regarding current conditions and the past decade of spread. Separating out ventenata from other exotic invasive annual grasses using remotely sensed information may be problematic (Noone et al. 2013), and the resultant map of ventenata may be a composite of this species and other exotic invasive annual grasses.

We will then use our map of ventenata presence to explore the intersection of ventenata and disturbance (fire, grazing and prior fuel treatments), looking for correlation (qualitative and quantitative) between the two. For example, the locations of past fires and fuel reduction treatments may be an important predictor for ventenata invasion. Data from the Starkey Experimental Forest and Range and other locations will be used to test the theory that grazing may promote ventenata invasion.

To project ventenata habitat in the future, we will replace historical climate variables used to map current ventenata distribution with the GCM outputs published by CMIP5 for the RCP 8.5 greenhouse gas emissions scenario (a rising pathway of CO2 leading to about 1370 ppm by the end of the century). While the RCP 8.5 pathway is a “pessimistic” storyline, it represents a “worst case scenario” that is appreciated for framing management scenarios. GCMs will be selected based on their performance ranking for the Pacific Northwest and climate representation (Rupp et al. 2013; e.g. Kerns et al. in review). We will use an archive of downscaled climate projections at 30-arc- second (~800 meter) spatial resolution developed on the NASA Earth Exchange scientific collaboration platform and being distributed through the NASA Center for Climate Simulation (NEX Downscaled Climate Projections, NEX-DCP30).

Objective 3a: Examine the post-fire response of ventenata to recent fires. We will measure the post-fire response of ventenata populations for the four major fires that occurred in the Ecoregion in 2015 (Canyon Creek Complex ,110,422 acres; Cornett-Windy Ridge 103,887 acres; Grizzly Bear Complex 82,659 acres; and Corner Creek, 29,660 acres) (Fig 1.) as well as 4-5 older fires (< 10 years old). We will focus on open areas with a matrix of forest. In each fire, twenty-five 40-m point transects will be installed randomly in each different condition areas, stratified in GIS: 1) Pre-fire ventenata presence: areas known (from plot data) or mapped (from Objective 1) as having ventenata before fire; 2) Expected/modeled ventenata presence: similar environmental conditions based on the predictive model developed in Objective 2; and 3) randomly located areas not fitting either condition. Sampling will be done using a single transect design (Herrick et al. 2015). Along each transect at 1-m intervals we will record: 1) all plants species, except ventenata/exotic annual grasses every 50-cm; 2); ground cover: litter, bare soil, rock/gravel, bedrock, cryptogams; 3) canopy gaps greater than 20-cm; and 4) residual evidence of high fire severity conditions in recently burned areas (modified from Hungerford 1996 e.g. remaining ground char, blackened shrub skeletons, etc.). Differences in response variables among the three landscape conditions will be assessed using a randomized complete block ANCOVA and Proc Mixed in SAS 9.4 (% high fire severity as a possible covariate, block/fire a random effect).

Objective 3b: Characterize ventenata populations along forested edges in invaded areas that have not burned. We will select 15 invaded scablands within a forested matrix (stratified by 2-3 forest types), based on accessibility and input from local managers, and establish twenty-five 40-m transects at the scabland-open area ecotone within each scabland. Transects will be randomly placed, starting 10-m from the forested edge, and characterized as four locations: open (0-10m from forested edge), forest edge (0-10m into forest from edge), forest edge/interior (10-20m from forest edge), and forest interior (20-30m from forest edge). Data collection along transects will follow protocols outlined in 3a, with the additional of overstory canopy cover every 50-cm. Data will be analyzed to examine differences among the forest types and edge locations using a randomized complete block ANCOVA and Proc Mixed in SAS 9.4 (overstory canopy cover as covariate, block/scabland a random effect). Fixed effects include forest type with 2-3 factor levels, and location along the ecotone with four factor levels. Statistician Patrick Cunningham (PNW) was consulted on the experimental design and statistical methods for Objectives 3a and 3b.

Objective 4. Examine how the ventenata invasion might change wildfire behavior now and in the future by developing operational scenarios. We will use the current ventenata invasion map developed in Objective 1, along with current canopy and surface fuel data, and historic weather and fire occurrence data, to run FSim for the BME. FSim (Finney et al. 2011) is a spatially explicit large fire occurrence and spread model that uses the minimum travel time spread algorithm (Finney 2002) to simulate thousands of large fires based on daily and seasonal weather. Inputs include a digital elevation model, canopy and surface fuel data, and historic weather and fire occurrence data, which will be obtained from publically-available datasets (e.g., the National Elevation Dataset).

We will also run FSim using our future ventenata spatial data for 3-5 climate change scenarios at two time periods: the middle and end of century. Future vegetation and fuel data, outside of the predicted ventenata map generated in Objective 2, will be created using output from the Dynamic Global Vegetation model MC2. MC2 is a dynamic vegetation model that projects climate change impacts on vegetation by simulating ecosystem biogeochemistry and vegetation biogeography and their interactions with fire (Conklin et al. 2015; Drapek et al. 2015; Vano et al. 2015). MC2 represents the landscape as a grid and runs on a monthly time step.

Future canopy and surface fuel data will be derived from MC2 by identifying correlations or relationships between vegetation output to fuel models and forest structure needed to run FSim. These future fuel landscapes will be constructed by translating current conditions as represented by Landfire (Rollins 2009) using the correlations we identify between MC2 results and the current landscape. MC2 will also generate gridded Energy Release Component (ERC) values under future conditions, for use by FSIM as ignition conditions. We will use the same GCM climate outputs as for Objective 2. MC2 has already been specifically calibrated for the BME as described in Kerns et al. in review. Developing the linkages between FSim and MC2 is an exciting and novel opportunity to directly link a fire simulation model with a vegetation dynamics model to explore scenarios across operational landscapes associated with future climate and vegetation conditions. This linkage will have widespread and important applications for other landscapes.

FSim outputs include information regarding the location and final fire perimeter for each fire simulated, as well as annualized burn probability and conditional fire intensity. Ignition location and final fire footprint can be used to understand the transmission of fire across a landscape. Burn probability and intensity can be used to assess the exposure to wildfire. This information could then coupled with estimations of the effect of fire on resources or values of interest as part of a wildfire risk analysis.

III. Project Duration and Timeline

We are proposing a 3-year study, starting September 2016, and ending December 31, 2019. The timeline is estimated below, organized by objective (Obj.). Specific deliverables are listed in Section VI.

Project Milestone Description	Obj.	Delivery Dates
Begin aggregation of field support data for ventenata map (in-kind USFS)	1	Spring '16
Collect limited field data in areas with little data (in-kind USFS)		Summer
Establish Joint Venture Agreement with OSU (via Krawchuk and Zald)		Fall '16
Continue aggregation of field support data for map		Late winter '16
Preliminary ventenata map created		Spring '17
Collect additional field support data and do map validation work		Summer '17
Final map complete		Fall-Winter '17
Develop current habitat suitability model for ventenata		Fall – Winter '17
Overlay management/disturbance and conduct assessment		Fall –Winter '17
Ten year change map complete		Spring '18
Create future map using NEX-DCP30 scenarios	2	Spring '18
Select and onboard OSU MS student	3	Fall '17
Scabland data collection		Summer '18
Enter/clean/analyze data		Fall-Winter '17
Thesis defended: Ventenata response to wildfire and scabland dynamics		Fall 2019
Development of integration methods for FSim MC2 linkage	4	Winter '16
Run MC2 with CMIP5 NEX-DCP30 scenarios		Spring '17
Gather spatial layers to run FSim for current conditions		Spring- Summer '17
Run FSIM for current conditions		Fall/Winter '17
Gather spatial layers to FSim for future conditions/crosswalk models		Winter '17-Spring '18
Run FSim for future landscape conditions		Fall '18 – Feb. '19

IV. Project Compliance – NEPA and Other Clearances - NA

V. Research Linkages

The proposal builds on the following other ongoing current and proposed research.

Fund Source	Description	Funding	Completion Date
JFSP 12-1-01-10	Effects of Prescribed Burn Regime and Grazing on Eastern Oregon Ponderosa Pine Vegetation and Fuels: The Season and Interval of Burn Study (Kerns)	$336,971	In progress; expires 6/30/2016)
JFSP	Long-term effects of restoration treatments in a Wyoming big sagebrush community invaded by annual exotic grasses (Kerns)	$35,969	In review
PNW and R6	Landscape Models that Incorporate Climate Change (Kerns and Kim)	$45,000	2014 (completed)
RMRS Nat. Fire Plan	Understanding the role of fire refugia in promoting ecosystem resilience (Krawchuk).	$486,000	In review
WWETAC and Eastside Restoration Team	Large fire simulation modeling for the Blue Mountains Forest Resiliency Project (Vaillant)	Internal - NA	In progress, est. finish 9/16

VI. Deliverables and Science Delivery

Products will target both land managers and research scientists. Results will be presented at ecological, invasive species, fire, and global change conferences. The Ecology and Management of Invasive Plants (EMAPi) conference is targeted because it offers an opportunity to transfer this work to the international community. The fire-grass cycle phenomenon is a global issue. Scientific papers (5-6) will be published. Workshops/field trips with managers are also planned. We will work with the Pacific Northwest Fire Science Consortium to conduct webinars (http://www.nwfirescience.org/) and post papers. Publications targeted to managers (e.g. Science Findings) will also be pursued.

Deliverable and description	Objective	Date
Map of ventenata invasion in the Blue Mountain Ecoregion	1-2	2017
Map of ventenata potential future invasion in the Blue Mountains		2018
Map of ventenata change 2004-2014		2018
Conference presentation (ventenata maps, EMAPi)		2017
Paper 1: current, future distribution		2018
Paper 2: links to disturbance/management		2018
Workshop w/Managers: Current & Future State of the Invasion		2018
PNW Fire consortium Webinar : Current & Future State of the Invasion		2018
PNW Science Finding: Current & Future State of the Invasion		2018
Conference presentation (invasive species, fire focus: ESA)	3	2018
Paper 3: ventenata dynamics in scablands (possibly 2 papers)		Late '18/2019
PNW Fire consortium Webinar : ventenata in scablands		Late '18/2019
Conference presentation (fire, global change focus: AGU)	4	2018
Paper 4: Methods for linking MC2 and FSim		2019
Paper 5: Fire behavior with current and future invasion		2019
Workshop w/managers: Fire behavior with current and future invasion		2019
PNW Science Finding: Fire behavior with current and future invasion		2019
PNW Fire consortium webinar: Implications of ventenata synthesis	All	2019
Final Report to JFSP	All	2019

VII. Roles of Investigators and Associated Personnel

Personnel	Role	Responsibility
Dr. Becky K. Kerns – PNW	Project PI	Oversight of study; co-leads research and advises graduate student w/Krawchuk for Objective 3; co-writes all papers
Dr. Harold Zald – OSU	Co-PI	Assists Kerns with study oversight/logistics; provides guidance and co-writes papers 2 and 5
Dr. Megan Krawchuk – OSU	Co-PI	Provides guidance and collaborates on all objectives; co-leads research w/Kerns and advises graduate student for Objective 3 co-writes paper 3
Dr. Nicole Valliant – PNW, WWETAC	Co-PI	Co-lead with Kim for research under Objective 4; runs FSIM; co-writes paper 4; writes/or co-writes paper 5
Dr. John Kim – PNW, WWETAC	Co-PI	Co-lead with Valliant Objective 4; runs MC2; co-writes paper 4; writes/or co-writes paper 5
Bridgett Naylor – PNW	Co-PI	Assists with overall logistics, provides GIS, remote sensing support; provides data from Starkey; manages USFS field crew, assists with data entry and analysis
Master's student – OSU	Collaborator	Oversees Objective 3 under Kerns/Krawchuk guidance, writes thesis, lead author on paper 3

Michelle Day – OSU	Collaborator	Provide science support to Kerns; assist with research under Objective 3; assists with budget and data mgt.
Dr. Lesley Morris – OSU	Collaborator	Provides collaborative support regarding ventenata ecology and response to fire
Dr. Warren Cohen – PNW	Collaborator	Provide expertise on Landsat satellite imagery and analytical methods
Dr. Sabine Mellmann-Brown – USFS Wallowa-Whitman NF	Collaborator	Blue Mountains zone ecologist, will collaborate on entire study and provide management input
Dr. David Pyke, USGS	Collaborator	Provides collaborative support regarding ventenata ecology
Dr. Gregg Riegel – USFS Deschutes NF	Collaborator	East-side OR zone ecologist, will collaborate on entire study and provide management input

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