FBGC Research Projects

Contents

Wildlife HSI

Modeling wildlife habitat suitability under potential future climate regimes, with incorporation of potential management strategies to restore and sustain critical habitat.

We are using the FireBGCv2 modeling platform to evaluate shifts in wildlife habitat suitability resulting from climate changes and shifting disturbance regimes. Landscape- and species-specific habitat suitability indices reflect potential occupancy based on dominant vegetation species and structural composition. These landscape attributes vary with changes in climate and following disturbance events such as wildfires or mountain pine beetle epidemics. Wildlife habitat suitability models can be used to 1) assess the potential of current landscapes to support specific wildlife species; 2) evaluate the effects of projected changes in climate and disturbance on landscape vegetation/habitat suitability; and 3) test suites of management strategies for restoring or maintaining critical habitat under future climate regimes.

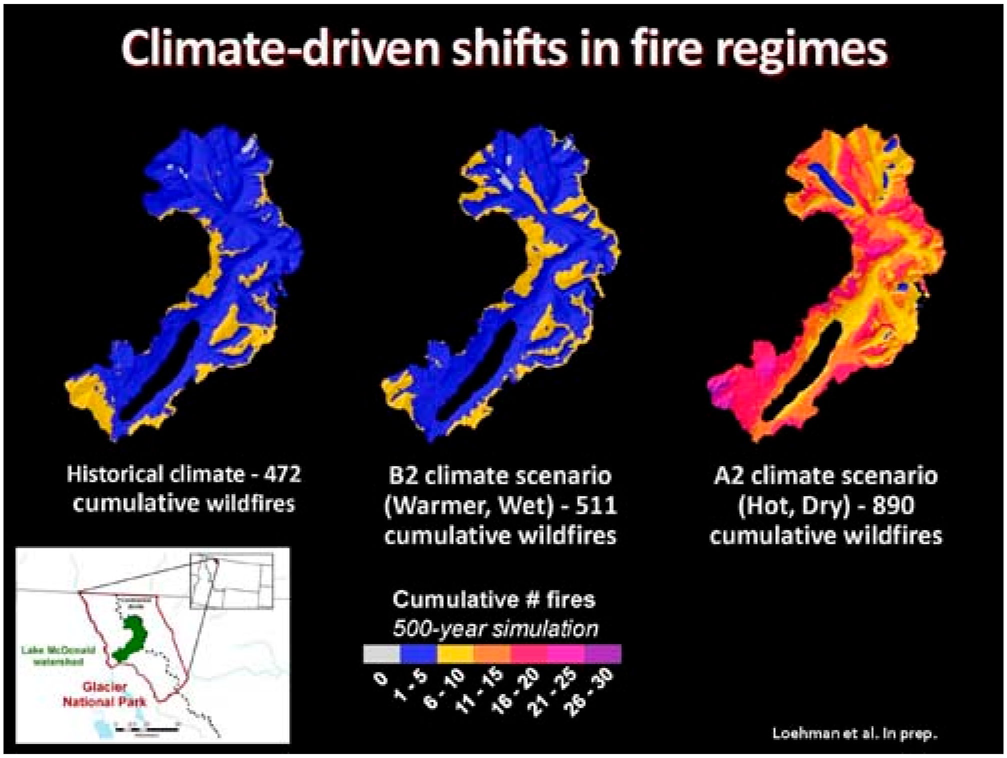
We have developed wildlife habitat suitability index (HSI) models for grizzly bears and Canada lynx in Glacier National Park, and are incorporating avian HSI models for species in Montana and Oregon. For more information on avian research visit the Birds and Burns Network.

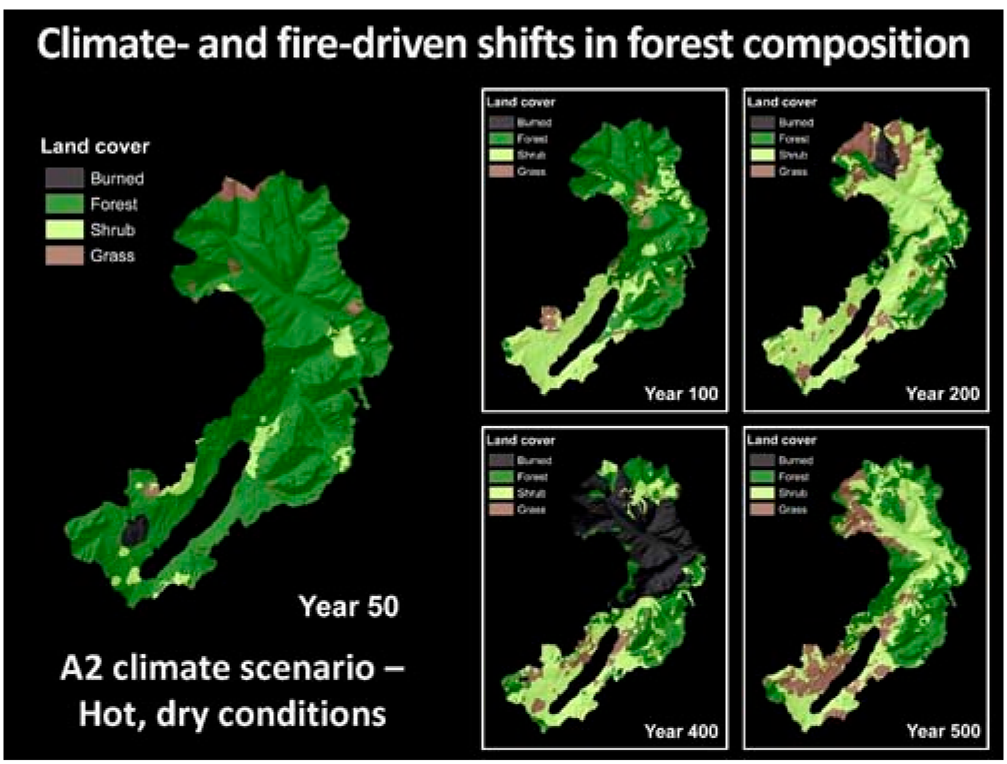
Photos: Some of the wildlife species included in the project – Elk and grizzly bear

CLIMET

Understanding species migration and fire dynamics under future climates

We incorporate multiple potential future climate regimes spanning a range of warm-wet and hot-dry conditions, and couple these with varying levels of fire management treatments and disturbance processes such as mountain pine beetle epidemics and white pine blister rust to evaluate the isolated and synergistic effects of climate, wildfires, and other disturbance on species distributions, vegetation structure, carbon balance, fuels accumulation, wildlife habitat suitability, and hydrologic dynamics. In addition, we evaluate climate effects on wildfire spatial patterns and severity, and test a variety of landscape restoration treatments under potential future climate regimes. Our results are synthesized across the simulation landscapes to quantify landscape vulnerabilities and potential climate- and wildfire-driven shifts in processes and functions across ecological gradients.





TIPPING POINTS:

Climate projections for the next 20-50 years forecast higher temperatures and variable precipitation for many landscapes in the western United States. Climate changes may cause or contribute to threshold shifts, or tipping points, where relatively small shifts in climate result in large, abrupt, and persistent changes in landscape patterns and fire regimes. Rather than simulate potential climate-fire interactions using future climate data derived from Global Climate Models (GCMs), we developed sets of progressively warmer and drier or wetter climate scenarios that span and exceed the range of GCM outputs for the western US, including temperature and precipitation combinations that may not be present in GCM projections by may occur at finer (regional or local) scales. These climate scenarios were used to simulate potential future fire and vegetation dynamics in three study areas in the western United States - McDonald watershed, Glacier National Park (MT), the central plateau of Yellowstone National Park (WY), and the East Fork Bitterroot River basin (MT). These landscapes encompass a diverse range of biophysical settings, vegetation species, forest structure, and fire regime, and thus were expected to differ in their sensitivity to climate changes and exhibit unique threshold behavior following climatic and wildfire perturbations. Each of the study areas proved sensitive to simulated changes in temperature and precipitation, as reflected in shifts in mean annual burned area, crown fire area, and fire-caused tree mortality. Sensitivity to climate changes differed across landscapes – for example, a significant decline in basal area occurred at temperature shifts of 3 °C and above for the Yellowstone National Park study area, 4 °C and above for the Glacier National Park study area, and above 5 °C for the East Fork Bitterroot River basin. Moreover, shifts in basal area were strongly related to changes in area burned and fire regime characteristics, suggesting that synergistic interactions of climate and fire will be important in determining future landscape patterns.

FIRECLIM

Assessing and adaptively managing wildfire risk in the wildland-urban interface for future climate and land use changes.

The effects of climate change and land and wildland fire management agencies' decisions on fuel loads, area burned, and ecological conditions in WUIs will be simulated at the 30-m2 resolution using a GIS-based, mechanistic ecological modeling system that integrates the FSPro (Fire Spread Probability), Fire-BGCv2 (BGC stands for biogeochemical), FARSITE (Fire Area Simulator), and FlamMap models. FSPro (Fire Spread Probability) will be used to simulate fire ignitions in each WUI. FSPro is a spatial model that calculates the probability of fire spread from a current fire perimeter or ignition point for a specified time period (McDaniel undated). Fire-BGCv2 will be used to simulate tree growth, organic matter decomposition, litterfall and other ecological processes using detailed physical biogeochemical relationships. Fire-BGCv2 is a spatially-explicit, stochastic, tree succession model that produces a spatial simulation of fire on a landscape (such as a WUI) and assesses the effects of fire on ecosystem conditions (Keane et al. 1996ab; 1997; 1999) using probability functions with ecologically-derived parameters. Primary canopy processes of interception, evaporation, transpiration, photosynthesis, and respiration are simulated at a daily time step at the stand-level. Driving variables for these processes will be taken from daily weather data extrapolated across the WUI using the DAYMET program and database (Thorton et al. 1997). DAYMET generates daily surfaces of temperature, precipitation, humidity, and radiation over large regions of complex terrain (http://www.daymet.org/). Fire ignition will be stochastically simulated based on weather and fuelbed characteristics. First, the project area landscape will be projected forward in time for 100 years under the various climate change and land management scenarios and various maps of landscape conditions, including fuels, vegetation, and productivitiy, will be output every 10 years. These maps will be used as inputs to FSPro, FARSITE, and FLAMMAP to calculate spatially explicit maps of fire risk and hazard. Growth, spread (i.e., area burned), and behavior of fire will be mechanistically computed using the Rothermel (1972) fire spread model as implemented in the FARSITE model (Finney 1998). FARSITE is a fire behavior and growth simulation model that simulates the spread of wildfires across a landscape (USDA Forest Service 2003) (Figure 7). Average simulated fire behavior across stands in a WUI will be used to calculate fuel consumption and tree mortality (Keane et al. 1996a). The area burned under each CLEW future and for each year of the evaluation period will be estimated by inputting simulated fuel loads and landscape attributes for pixels to the FARSITE and FlamMap models (Finney et al. 1998; Farris et al. 1999). FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics (i.e., spread rate, flame length, fireline intensity, etc.) over an entire FARSITE landscape for constant weather and fuel moisture conditions. FSPro, Fire-BGCv2, FARSITE, and FlamMap will be used to simulate landscape and fire dynamics in all future WUIs in Flathead County (and possibly pixels adjacent to the boundaries of WUIs) for three to four land and wildland fire management practices and three climate change scenarios over a 50-year period at a 30-m2 pixel resolution. Management practices will be implemented across WUIs based on parameters (e.g., treatment stand characteristics, acres treated per year, and harvest diameter ranges) specified by the project team in collaboration with the land and wildland fire management agencies' panel. The effects of management practices and climate scenarios on ecological conditions in WUIs will be evaluated based on the concept of historical range of variability (HRV) (Holsinger et al. 2006). In particular, spatial and tabular output from the Fire-BGCv2 model from a 5,000-year simulation parameterized with *historical* fire regime and weather data will be compared to the simulations of *future* landscapes under alternative management practices and future climate scenarios to determine how close or departed the future simulated landscapes are from their HRV.

PALEOBGC

Past, present, and future forest resilience: Linking ecosystem process models with multicentury fire histories from tree rings.

Managing for resilient future forests – those that can forestall undesired effects of climate change or rebound to an initial state following disturbance – requires that we both understand how forests functioned in the past and predict how fire regimes and forests may change with future climate change and land management. Tree rings provide a uniquely detailed, long-term understanding of past fire regimes and forest function. Local fire and forest histories of fine-scale temporal and spatial resolution (1000s of hectares) have been reconstructed from tree rings across gradients of topography and vegetation. Managers consistently ask for and use these local histories in situ, but are asking additional questions that cannot be answered by tree rings alone: (1) can local fire and forest histories be extrapolated to unsampled areas; (2) do present fire regimes and forest conditions depart from historical ones; (3) what will future fire regimes and forest conditions be given changing climate and land management? These questions about the future involve identifying thresholds (i.e., tipping points) of future change that may alter some ecosystems beyond their historical range and variability, predicting changes in habitat suitability for a range of wildlife species, and assessing interactions among multiple disturbances and stressors (e.g., climate, wildfire, and insect activity). Simple statistical extrapolations of tree-ring reconstructed fire and forest histories across space and through time may overlook ecological processes that operate at broad landscape and regional spatial scales and decadal and multicentury time scales. Conversely, models can be used to simulate ecosystem dynamics across broad areas, but few calibration data sets for these models exist; fewer still include multiple centuries of observations, which are necessary to encompass long-term climate and ecosystem dynamics. Calibration of models with long-term historical data sets will produce robust results with reduced uncertainty, critical factors when applying model results to land management issues. To date, ecosystem process models have not been linked to long-term fire and forest histories.

We linked existing multicentury fire and forest histories with one of the only ecosystem process models capable of simulating the dynamic interactions of climate, natural and human disturbance, and vegetation - the FireBGCv2 modeling platform developed at RMRS. This model combines a mechanistic, individual tree succession model with a spatially explicit fire model incorporating ignition, spread, and effects on ecosystem components that can simulate multi-scale (landscape to individual species) climate-fire dynamics on real-world landscapes. We will use two of the Interior West's most extensive spatial networks of gridded fire and forest histories already reconstructed from tree rings by the PIs. These are based on more than 6,000 trees in central Oregon and 10,000 trees in Utah. These networks cover a broad range of fire regimes and forest types, and are thus perfectly suited for developing the link to the FireBGCv2 simulation model for the purpose of exploring the ecological impacts of future fire regimes.

FIRMTIP

Wildfires are major concerns across the western US because they have increased in frequency, intensity, and size in many areas and the costs to suppress these fires are also increasing. Continued suppression of wildfires may exacerbate the situation by allowing more biomass to accumulate to foster even more intense fires. Enlightened fire management involves explicitly determining concurrent levels of suppression, wildland fire use (allowing some fires to burn), and fuel treatments to manage landscapes for ecological resilience. In this study we used the mechanistic landscape model FireBGCv2 to simulate ecological dynamics on three landscapes in the US northern Rocky Mountains to determine responses of seven management-oriented variables over a gradient of ten fire suppression levels under two climate and four fuel treatment scenarios. We used a historical range and variation (HRV) time series of the seven variables individually and merged together as a Principal Components factor (PC1) to define the envelope that defines ecological resiliency and compared all simulations to the HRV base case. We found that under today’s climates using the PC1 factor, ecological resilience was maintained while suppressing 30-60% of wildfires on the landscape with frequent fire, suppressing 80-90% for the mixed fire regime landscape, and up to 98% on the infrequent, stand-replacement fire landscape. We also found fuel treatments may allow higher suppression levels to occur and still maintain resilience, but only when suppression levels were over 80%. Under future climates, fire suppression seemed to move or keep landscapes within HRV resilience envelopes depending on landscape. Other findings indicate that each landscape must be individually evaluated to determine the right mix of wildfires, wildland fire use, and fuel treatments, and this mix is greatly dependent on the response variables used to evaluate resilience.

WildFIRE PIRE

Feedbacks and consequences of altered fire regimes in the face of climate and land-use change in Tasmania, New Zealand, and the western U.S. (http://www.wildfirepire.org/)

While field studies of wildland fire dynamics provide the foundation for fire sciences, ecological modeling has a critical role by allowing field data to be integrated with other ecological research to explore fire interactions in space and time. Simulation modeling provides an effective, standardized, and objective context to evaluate fire regimes and ecological change. Mechanistic landscape models can be used to explore fire, climate, and vegetation interactions and to quantify fire regimes in space and time. Most importantly, simulation models can help predict potential fire dynamics under future climates to provide fire scientists critical information to mitigate any adverse effects. Last, and most importantly, models can be used to extrapolate and expand field study results across large temporal and spatial scales.

We will apply the FireBGCv2 model to three 50-100K ha landscapes; 1) Yellowstone National Park in the United States, 2) a landscape in New Zealand to be named later, and 3) a landscape in Tasmania to be named later. The resolution, extent, and detail of the landscapes will be decided in future. All modelers will be encouraged to apply their models to these three landscapes but they will be responsible for teaching the model to the post-doc. All input map layers, parameterizations, and initial conditions will be documented and posted to the web site. The YNP study landscape has been sampled and all digital maps have been collected and can be posted by September 2011. Information on the Tasmania or New Zealand study landscapes will either be supplied by the cooperators or collected by the Wildfire-PIRE personnel.

We will explore landscape-climate-fire-vegetation dynamics using FireBGCv2 and all other models using a simulation experiment that employs scenarios to describe model behavior under various conditions. Under this format, we will specify a set of scenarios that are designed to emphasize differences in model behavior over diverse climate, fire, and vegetation conditions. Presented here is the draft experimental design; the actual simulation experiment design will be formalized over Year 2 through interaction with modelers and Wildfire-PIRE collaborators. The following primary scenarios and levels will be simulated:

- **Climate**. Four different climate scenarios will be simulated
  - Historical climates. Paleoclimatic scenarios will be developed by the Wildfire-PIRE scientists and used as input to the model.
  - Contemporary scenario. Taken from weather data collected for the target landscapes.
  - B2 scenario – Warm Moist. A synthesis of the B2 scenario will be compiled from the seven GCMs for each landscape.

- A2 scenario – Warm Dry. A synthesis of the A2 scenario will be compiled from the seven GCMs for each landscape
- **Fire Ignitions**. Several fire scenarios will be simulated to mimic past, current, and future fire ignition patterns.
  - Lightning ignitions. Random ignition patterns will be simulated.
  - Aboriginal ignitions. Ignition patterns will be simulated based on spatial data of past aboriginal land use.
  - Future ignitions. A digital layer of future ignition probabilities will be developed based on predicted land use and fire management plans.
- **Exotic Invasion**. Two scenarios will be used to explore the effect of exotic invasions on fire regimes and vegetation dynamics.
  - No exotics. Only native species will be modeled.
  - Exotics. Exotic species will be included in the simulation.

Many response variables will be used to detect changes between scenarios and models. These response variables are scale dependent and reflect the variables need to successfully complete the simulation objectives. They are output in tables and digital maps. They can be modified and others can be added later:

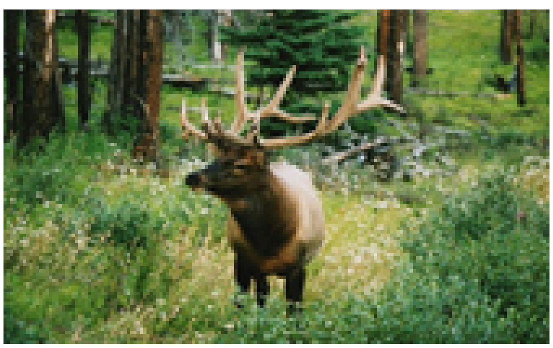
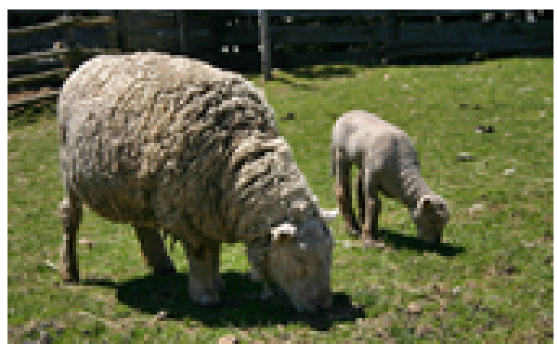
- **Landscape.** Fire rotation (yr), fire return interval (yr), carbon (kg/m2, NPP, NEP, GPP, NEE, fireC, abovegroundC, belowgroundC), pollen load, charcoal deposition.
- **Stand**. Fuels (coarse woody, fine woody, litter, duff, shrub, herb), carbon (same as above), structure (dominant species, canopy cover, basal area, density), exotics (abundance)
- **Fire**. Fire intensity, severity, tree mortality, fuel consumption, carbon emissions.
- **Tree**. Species distribution and species.

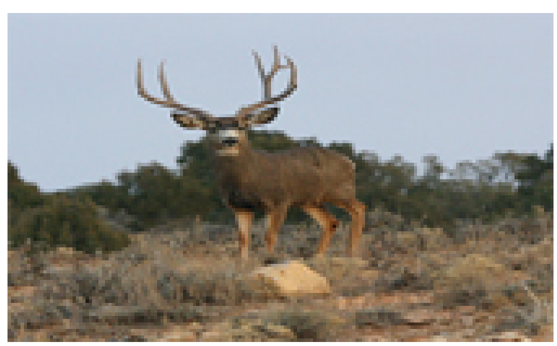
Models will be initialized using local vegetation, fire, topography, soils, and climate data collected for each landscape. Parameterization of the models will be done for each landscape using data collected during past studies, literature reviews, and Wildfire-PIRE data collection. We will run the model for 500 years and output response and explanatory variables are decadal timesteps. We will also output maps of fire intensities, severities, and vegetation composition. For the paleoclimatic scenarios, we will run the model for 14,000 years to attempt to replicate the paleo-record of pollen and charcoal. Results will be analyzed using MANOVA, regression tree, and multivariate techniques to determine the subtle differences and similarities between and across the three landscapes by scenario.

GRAZE-BGC

Strategic role of large herbivore grazing on succession, fuels, and fire dynamics in a changing climate.

Vegetation mosaics are shaped by multiple driving factors that interact across time and space. Climate, fire, forest practices, and grazing by large herbivores typically operate together in landscapes, and interactions and feedbacks among these factors can challenge efforts to predict vegetation dynamics. Succession and episodic disturbance can be modeled interactively with spatially-explicit Landscape Fire Succession Models (LFSMs), but these models have yet to fully integrate ungulate herbivory as an interactive driver of succession. We modified a complex LFSM, FireBGCv2, to include a spatially-explicit herbivory module, GrazeBGC. The resulting system integrates multi-herbivore stocking, inter- and intra-specific forcing of grazing intensity, and herbivore dietary selectivity to modify fuels, which contribute to landscape fire regimes. A full factorial experiment in a 9,000-ha grass-tree mosaic with five grazing regimes (no herbivores, wildlife-only, livestock-only, wildlife + livestock, wildlife + double livestock), three climates (historical, B2: +3oC, A2: +6oC) and two fire-management scenarios (historical fire, fire suppression) generated interactive influences on spatially-explicit undergrowth biomass (shrub, herb, total) and surface-fire (intensity; flame length; scorch height; soil heat; smoke CO, CO_2, CH_4, $PM_{2.5}$). Effects increased with herbivore biomass demand, but also with biophysical site productivity, fire-suppression, and climate change. Multi-species grazing that approximated historical herbivore populations significantly modified stand-scale biomass and fire behavior, but less intense grazing regimes that involved only wildlife or only livestock were less effectual. However herbivory's effects at that scale were contingent on the landscape's future regimes for fire suppression and climate, which together interacted with herbivory to modify the accrual of undergrowth biomass over time. Stand-scale effects of grazing affected the landscape's fire-return interval as well, but otherwise did not "scale up" to significantly modify respiration, primary production, carbon, or the total area burned by individual fires. As modeled here, potential climate change and future fire suppression exerted stronger effects on fire behavior and metabolism at landscape scale than did herbivory, probably because those agents influenced more fuel components than did herbivores in this forest-dominated vegetation mosaic.

FISHFRY

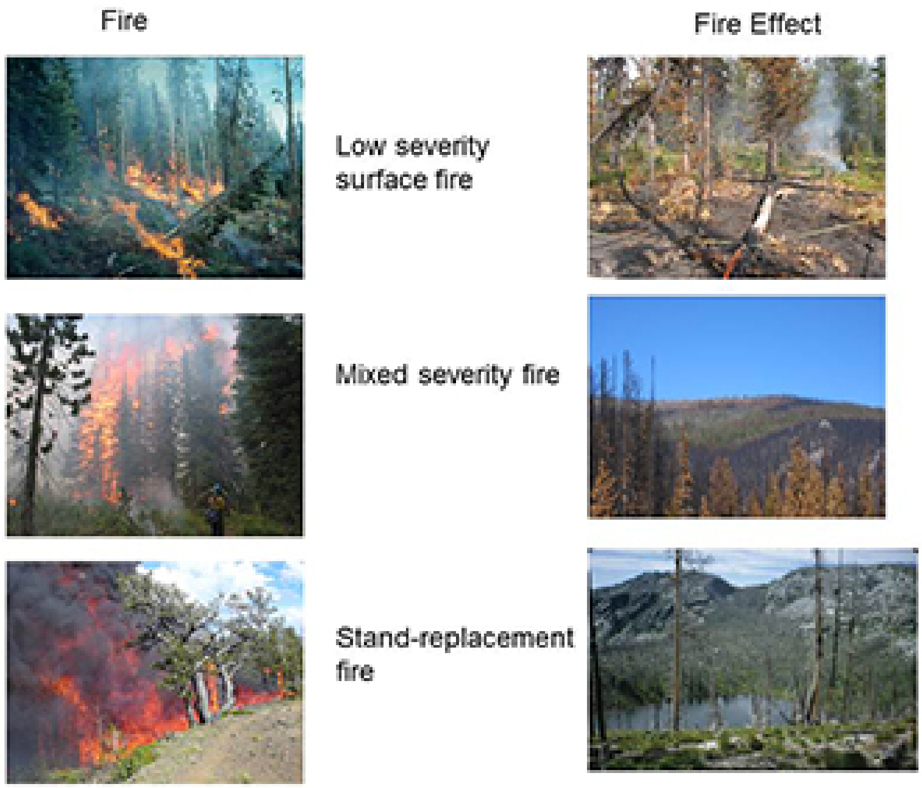
Wildland fire affects native fishes sin the Rocky Mountain West by removing riparian vegetation, increasing solar radiation to the stream, and leading to warmer summer water temperature.

Thermal regimes in freshwater ecosystems are warming in response to increases in air temperature associated with global climate change. Projected changes in climate are also expected to change fire regimes across the western US, which could increase stream temperatures by reducing shading associated with near-stream vegetation. We linked a statistical regression model predicting daily stream temperatures to a spatially explicit landscape fire and vegetation model (FireBGCv2) to explore interactions among vegetation, disturbance, climate and hydrology across a montane landscape in the Northern Rocky Mountains. Specifically, we were interested in how stream temperatures might respond to future climate change (i.e. A2, B2 climate scenarios) in a fire-prone watershed and the role that fire management actions such as fuel reduction and fire suppression could play in tempering stream thermal responses. We found that basin scale air temperature increases associated with future climate scenarios would account for a larger proportion of stream temperature increases than changes in wildfire regimes. Moreover, imposing various fire management strategies to limit the prevalence of wildfires had no discernible effect on basin scale stream temperature patterns. These patterns emerge because wildfires typically affect only a subset of streams in a network and because climate-induced shifts to fire and vegetation patterns promoted transition from a historically mixed to a non-lethal surface fire regime where lower fire severities lessened effects on stream temperature. Additional refinement is needed to improve techniques for estimating fire disturbance effects on stream temperature, but this study indicates that although wildfire may cause locally important, short-term increases in stream temperature, rising air temperatures from climate change will be the primary factor that causes departures from historical stream temperatures in this mountainous watershed.

GNLCC

Whitebark pine (Pinus albicaulis) forests are declining across most of their range in North America because of the combined effects of mountain pine beetle (Dendroctonus ponderosae) outbreaks, fire exclusion policies, and the exotic pathogen Cronartium ribicola, which infects five-needle white pines and causes the disease white pine blister rust. Predicted changes in climate may exacerbate whitebark pine decline by (1) accelerating succession to more shade tolerant conifers, (2) creating environments that are unsuitable for the species, (3) increasing the frequency and severity of mountain pine beetle outbreaks and wildland fire events, and (4) facilitating the spread of blister rust. Yet, whitebark pine tolerates a variety of stressful conditions and has the broad genetic diversity to adapt to changes in climate and disturbance. The on-going decline in this high-elevation tree species poses serious

consequences for upper subalpine and treeline ecosystems and, as a consequence, whitebark pine is now a candidate species for listing under the Endangered Species Act. The large, nutritious seeds produced by this pine are an important food for many bird and mammal species, and whitebark pine communities provide nesting sites and habitat for many other wildlife species. Whitebark pine seeds are dispersed long distances by Clark's nutcrackers (Nucifraga columbiana), which cache seeds in a variety of terrain and community types, including recent burns and other disturbed areas. The unclaimed seeds often germinate and produce hardy seedlings. These seedlings can survive on harsh, arid sites, and act as nurse trees to less hardy conifers and vegetation. Since more than 90 percent of whitebark pine forests exist on public land in the United States and Canada, a trans-boundary, range-wide whitebark pine restoration strategy was developed to coordinate and inform restoration efforts across federal and provincial land management agencies. However, this restoration strategy failed to fully address projected effects of climate change on whitebark pine restoration efforts and existing stands. In this report, we present guidelines for restoring whitebark pine under future climates using the range-wide restoration strategy structure. General restoration guidelines considering effects of climate change are given to each of the strategy's guiding principles: (1) promote rust resistance, (2) conserve genetic diversity, (3) save seed sources, and (4) employ restoration treatments. We then provide specific guidelines for each of the strategy's actions: (1) assess condition, (2) plan activities, (3) reduce disturbance impacts, (4) gather seed, (5) grow seedlings, (6) protect seed sources, (7) implement restoration treatments, (8) plant burned areas, (9) monitor activities, and (10) support research. We used information from two sources to include climate change impacts on whitebark pine restoration activities. First, we conducted an extensive and comprehensive review of the literature to assess climate change impacts on whitebark pine ecology and management. Second, we augmented this review with results from a comprehensive simulation experiment using the spatially explicit, ecological process model FireBGCv2 that simulated various climate change (RCP4.5 and RCP8.5), management (thinning and prescribed burning, planting), and fire exclusion (90 percent suppression, 50 percent suppression, no suppression) scenarios. We analyzed two simulated response variables (whitebark pine basal area, proportion of the landscape that is whitebark pine dominated) to explore which restoration scenarios have the best chance of succeeding in the future. We also ran FireBGCv2 to evaluate the effects of specific rangewide restoration actions with and without climate change. Our findings indicate that, with management intervention in the form of planting rust-resistant seedlings and employing proactive restoration treatments, whitebark pine can be returned to the high mountain settings of western North America to create resilient upper subalpine forests of the future. The report is written as companion guide to the rangewide restoration strategy for planning, designing, implementing, and evaluating fine-scale restoration activities for whitebark pine by addressing climate change impacts.


Fire
Fire Effect
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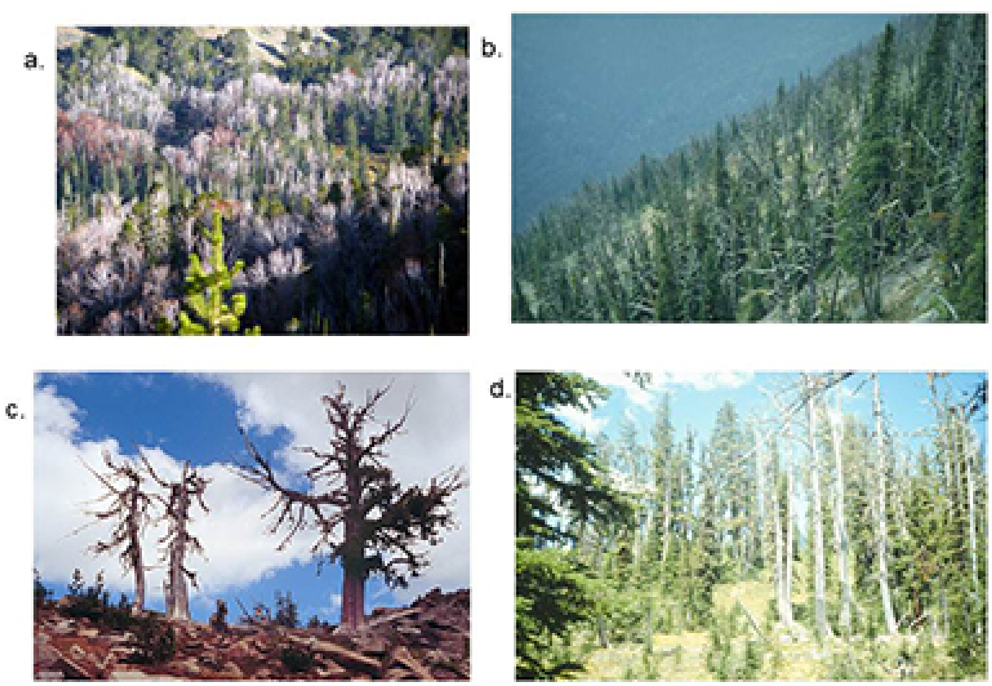
Mixed severity fire
Stand-replacement fire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