SYMPOSIUM: Global change and ecosystem resilience: managing threats to sustainability

Across Time & Space: Species diversity response to fire severity in Sierra Nevada yellow pine and mixed-conifer forests

Topic: Natural areas management in light of climate change

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Ecological disturbance regimes are changing due to a combination of effects from both direct human influences and climate change. Wildfire regimes in particular are being affected due to interactions between high fuel loads and climate warming, resulting in many regions that historically experienced low to moderate fire severity regimes now seeing increased area burned at high severity. Despite understory taxa comprising the vast majority of forest plant species and playing vital roles in overall ecosystem function, little is known of the effects of changing fire regimes on forest understory plant diversity. Furthermore, the role of time since fire when examining the relationship between fire severity and diversity is understudied, with space for time substitutions often being made. We examined understory plant diversity across gradients of wildfire severity in eight large wildfires in yellow pine and mixed conifer temperate forests of the Sierra Nevada, California, USA. Additionally, we sampled one of those fires at five time-steps across nine years. We found a generally unimodal relationship between local plant diversity and fire severity across fires and through time. High severity burning resulted in lower local diversity as well as some homogenization of the flora at the regional scale. Our research suggests that increases in fire severity in systems historically characterized by low and moderate severity fire may lead to plant diversity losses, which on a global scale may have important implications for biodiversity.

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Estimating loss of carbon stocks in postfire chaparral shrublands in southern California

Topic: Natural areas management in light of climate change

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Carbon sequestration is one of the many ecosystem services provided by chaparral shrublands in Southern California, however chaparral's effectiveness in providing this service is dependent on its resilience to mitigate disturbance. Estimates of carbon stocks pre- and post-fire in chaparral where fire occurrence is within the historical range is directly quantifiable (e.g., aboveground, belowground, litter, soil carbon), but quantification of stocks in areas with short fire return intervals and tailored to the different functional life histories of chaparral species (seeders versus resprouters) has yet to be determined. We estimated carbon stocks through compiling biomass estimates from the literature to build regeneration models for the seeder and resprouter life history types. We then integrated our models with Landsat-derived Enhanced Vegetation Index (EVI) and historical fire perimeter data to estimate changes in carbon stocks in chaparral pre- and post-fire. Carbon stocks were disproportionately affected in areas with the shortest fire return interval which was mainly driven by changes in the vegetation composition. The greatest losses occurred in type-converted landscapes that are heavily dominated by resprouter life history types, which store a higher proportion of biomass belowground compared to seeders. Our methods could be applied to environmental damage assessments to estimate the amount of carbon permanently lost due to fire and changes in fire regime.

Fire severity and productivity influence diversity patterns in California's subalpine forests

Topic: Managing fire regimes in a changing world (good fire/bad fire)

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In subalpine forests of the North American Mediterranean climate zone, climate-fueled changes in snowpack and growing season are contributing to larger and more frequent fire events. Changing fire regimes have resulted in biodiversity declines in lower elevation mixed conifer forests, which have low resilience to large patches of high severity fire. However, the risk of high severity fire to diversity in Mediterranean-type subalpine systems is uncertain. The influence of disturbance severity on species diversity is expected to depend in part on ecosystem productivity, but this theory has not been adequately tested in the context of fire and forest ecosystems. This study aims to help elucidate the effect of productivity on the species richness-fire severity relationship as well as to understand the effect of fire severity on species richness in Mediterranean-type subalpine forests. To answer these questions, we sampled understory richness in plots spanning a wide range of fire severity and across 13 fires in California's subalpine forest. In general, post-fire species richness increased with fire severity and decreased with productivity. The interaction between fire severity and productivity was also significant, with species richness increasing more across the fire severity spectrum in high productivity plots than in low productivity plots. Further, high severity plots had 3 times as many unique species as unburned plots and 2 times as many as low severity plots, suggesting that increased richness in high severity plots is driven by flora that can take advantage of the post-fire environment. Accordingly, the number of species with the classic colonizer traits of short lifespan and long-distance dispersal ability increased significantly with fire severity. Our results suggest that ecosystem productivity is an important predictor of the richness-fire severity relationship and that the projection of potentially higher fire severity in high elevation forests may be neutral to positive for species richness.

Fire, carbon, and climate change in California's high elevation forests

Topic: Natural areas management in light of climate change

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Recent changes in high elevation forests worldwide indicate that forest structure and long-term ecosystem stability are threatened, with implications for carbon sequestration and ecosystem refugia. Biomass and disturbance models have high uncertainty in high elevation forests, where landscapes are more heterogeneous across short distances and data are more limited than in lower elevations. Anecdotally, subalpine tree mortality after fire is generally low in the first year, with substantial increases in mortality in the five years following. Delayed mortality and compounded disturbances may lead to an underestimation of mortality from disturbances. Given the increasing area and frequency of fires over the last decades, changes in high elevation forest fire regimes and their impacts on biomass are unclear. In this project I analyze temporal patterns of tree mortality using Bayesian machine learning methods with high resolution imagery. I expect the timing of mortality in the several years following fire to vary between drought and non-drought post-fire conditions, and locations, with implications for long-term carbon storage projections and management. California's high elevations are assumed to be stable carbon sinks due to relatively low levels of disturbance, however the severity of disturbances may be underestimated using current methods. Enhanced measurements of post-fire mortality will impact assessment of changing biomass stocks, which is essential for understanding current and projected trends in carbon sequestration.

Global change and ecosystem resilience: managing threats to sustainability

Topic: Natural areas management in light of climate change

Hugh Safford
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This oral session, jointly sponsored by UC-Davis and the University of Nevada-Reno, centers on global change in western ecosystems and how managers are trying to ensure sustainability in the face of shifting disturbance and stress regimes. Focus is on western forests, chaparral, sagebrush, and meadow ecosystems. Speakers will discuss how interactions among drought, climate warming, fire, grazing, pests and pathogens are affecting ecosystem composition, structure and function, how management is impacted, and how management tactics and strategies may need to change to enhance ecosystem resilience and/or ensure long-term sustainability.

Implications of changing fire regimes for Sierra Nevada bat and bird communities

Topic: Managing fire regimes in a changing world (good fire/bad fire)

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Managing ecosystems for multiple objectives and multiple taxa is challenging under any circumstance but especially given uncertainties surrounding how biological communities will respond to changing fire regimes. To inform conservation and management efforts we studied the response of bats and birds to fire-induced changes in habitat and landscape pattern. For the bat community we conducted acoustic surveys in and around three wildfire areas during 2014-2017 in conifer forests of California's Sierra Nevada. We tested effects of mean burn severity and its variation, or pyrodiversity, on bat occupancy and diversity using hierarchical models that account for imperfect detection. Of the 17 species that occur in the region, occupancy rates increased with severity for at least 7 and with pyrodiversity for 2. Species richness increased from 8 species in unburned areas to 11 species in moderate- to high-severity burned areas with high pyrodiversity. We contrast these results with studies of avian post-fire habitat relationships in the region. While many bats appear to benefit from wildfire, even high-severity wildfire, bird responses are more mixed. As wildfires continue to grow larger with more area at risk of type conversion from forest to sustained early successional habitat, some species will benefit in the short-term while others lose habitat. Managing for resilience requires understanding how altered disturbance regimes are affecting all components of an ecosystem. For fire-adapted systems, actions that encourage mixed-severity wildfire and pyrodiversity will likely benefit the most species across taxa by limiting habitat extremes such as overly dense, fire-suppressed forests and very large high-severity patches.

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Management to promote the resilience of sagebrush ecosystems: invasive species, altered fire regimes, and climate change

Topic: Natural areas management in light of climate change

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In the sagebrush semi-desert of the western United States, the invasion of fire-adapted annual grasses such as cheatgrass (Bromus tectorum) can initiate a grass-fire cycle that results in the progressive loss of native plant communities. Climate change is exacerbating this risk by increasing the size and frequency of wildfires, expanding the climate niche of cheatgrass and other invaders, and reducing the recovery of native perennial species. The resilience of sagebrush ecosystems to fire is highly variable in space and time, and many recent fires have resulted in the conversion of large areas of valuable habitat to annual-grass-dominated ecosystems. There is thus a pressing need to identify management strategies that can promote ecological resilience given the interacting effects of invasive species, altered fire regimes, and warming climate. In this talk, we will discuss post-fire management options for promoting vegetation recovery in heterogeneous landscapes, based on the results of multiple long-term studies. We will show how landscape-scale post-fire recovery potential is related to environmental characteristics and pre-fire biotic conditions, emphasizing the need to target management efforts in those portions of the landscape that will benefit the most. For example, in the driest portions of the landscape where resilience to fire and resistance to cheatgrass invasion are both low, post-fire management interventions are unlikely to result in the successful restoration of native ecosystems. In contrast, post-fire management interventions are often unnecessary in cool and moist sites at higher elevations, where the rapid recovery of native perennials characterizes a resilient post-fire response. Post-fire management investments often have the greatest benefit in intermediate environmental conditions, including in mosaics of sagebrush shrublands and pinyon-juniper woodlands, where interventions such as seeding have the potential to greatly increase resistance to annual grass invasion. We will share experimental results that demonstrate the effectiveness of post-fire native seeding treatments and will show how functional diversity can be an effective bet-hedging technique for seeding into heterogeneous landscapes. We will then share research on climate-driven episodic establishment patterns in big sagebrush, discussing how an adaptive management approach that includes repeated seeding can minimize the risk of recovery failure for sagebrush and other key species. Finally, we will discuss how post-fire recovery potential is expected to shift in response to climate change, including increases in the proportion of the landscape characterized by low resilience to fire, and will present management principles for promoting ecosystem adaptation and reorganization in a time of increasing uncertainty.

Prioritizing Post-fire Restoration in Chaparral Shrublands in Southern California

Topic: Natural areas management in light of climate change

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The occurrence and size of wildfires in southern California have increased with human population growth. Chaparral vegetation recovery in post-fire landscapes can be impeded by a number of factors, including drought, excessive fire, and non-native species. Active restoration may be needed to enhance native shrubland recovery in areas affected by these stressors, yet across large fire scars identifying the need for restoration can be challenging. We developed a Post-fire Restoration Prioritization (PReP) tool to aid resource managers with early detection and prioritization of degraded chaparral landscapes in need of restoration. The PReP tool incorporates information on the post-fire regeneration strategy of plant communities and its interaction with fire history, pre- and post-fire drought, and non-native annual species to predict where recovery may be impeded, thereby identifying candidate areas for restoration. The tool also integrates spatial data on erosion risk for recent fires, so that areas in need of restoration can be prioritized for hillslope stabilization. Outputs from the tool can also be integrated with hotspots of ecosystem service provision and accessibility data to further refine restoration decision making. We demonstrate a proof of concept using the Copper and Powerhouse fires on the Angeles National Forest in southern California and find that 1,642 acres (10%) and 3,786 acres (14%) respectively are predicted to have low regeneration capacity and need restoration. Through field monitoring, we verified that areas predicted to have the lowest regeneration capacity indeed had the highest cover of non-native annual grasses and herbs and the lowest cover of native shrubs. The framework of the PReP tool is transferable to chaparral ecosystems across southern California and can guide management decision making to ensure long-term sustainability of chaparral and the ecosystem services it provides.

Projected impacts of climate change on northeastern California vernal pools

Topic: Natural areas management in light of climate change

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Vernal pools are ephemeral wetlands characterized by complete inundation during the winter and spring, followed by hot, arid conditions during the summer. Plant and animal species that occur in vernal pools are highly specialized to tolerate these fluctuating conditions, and vernal pools exhibit zonation of plant community types according to the tolerance of individual species to the local inundation regime. Vernal pools across California have been extensively destroyed since the mid-1800s as a result of agricultural conversion and urban development, and many vernal pool specialist species have been federally listed as threatened or endangered. Remaining vernal pools have been degraded by activities that modify vernal pool hydrology, including the construction of dams, ditches and roads. An emerging threat to vernal pools is hydrologic alteration caused by changes in precipitation and temperature as a result of climate change. We used hydrologic models in combination with hydroregime and vegetation sampling to investigate the potential impacts of climate change on vernal pools in northeastern California. Our model simulations suggest that climate change would result in sharp reductions in vernal pool hydroperiod, which in turn would lead to declines of the long-term inundated plant community, whereas edge and shallow-tolerant communities would increase. Vernal pool specialist species of primary conservation concern are more commonly found in the long-term inundated community, while short-inundated communities are characterized by wetland generalist and non-native plant species. However, our results also suggest that management actions may be able to partially mitigate some of the predicted effects of climate change. For example, restoration of vernal pool hydrology may extend vernal pool inundation period in some cases. In addition, we found that litter accumulation associated with livestock exclusion may decrease inundation lengths in vernal pools. Our results are consistent with a number of other studies suggesting that active management of vernal pool landscapes to limit litter accumulation may also be necessary to maintain vernal pool hydroregimes in the face of climate change.

Recent bark beetle outbreaks influence wildfire severity in mixed-conifer forests of the Sierra Nevada, California, USA

Topic: Managing fire regimes in a changing world (good fire/bad fire)

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Rebecca B. Wayman and Hugh D. Safford.

In temperate forests, elevated frequency of drought related disturbances will likely increase the incidence of interactions between disturbances such as bark beetle epidemics and wildfires. Ecosystem management relies on sound information from analogous forest types, yet our understanding of the influence of recent drought and insect-induced tree mortality on wildfire severity has largely lacked information from forests historically experiencing frequent fire. A recent unprecedented tree mortality event in California's Sierra Nevada provides an opportunity to examine this disturbance interaction in historically frequent-fire forests, filling an important gap in a body of evidence drawn largely from forests adapted to severe, infrequent fire. Using field data collected within areas of recent tree mortality that subsequently burned in wildfire, we examined whether and under what conditions wildfire severity relates to severity of pre-fire tree mortality in Sierra Nevada mixed-conifer forests. We collected data on 180 plots within the 2015 Rough Fire and 2016 Cedar Fire footprints. Our analyses identified pre-fire tree mortality as influential to all measures of wildfire severity (basal area killed by fire, RdNBR, and canopy torch) on the Cedar Fire and to two of three measures on the Rough Fire. Factors such as fire weather and topographic position also strongly influenced wildfire severity. On the Cedar Fire, the influence of pre-fire mortality on wildfire severity was greater under milder weather conditions. All measures of fire severity increased as pre-fire mortality increased up to pre-fire mortality levels of approximately 30-40%; further increases did not result in greater fire severity. The interacting disturbances shifted a pine dominated system to a cedar/pine/fir dominated system, while the pre-disturbance fir/cedar system retained its species dominance. Managers of historically frequent-fire forests will benefit from utilizing this information when prioritizing fuels reduction treatments in areas of recent tree mortality, as it is the first empirical study to document a relationship between pre-fire mortality and subsequent wildfire severity in these systems. This study contributes to a growing body of evidence that the influence of pre-fire tree mortality on wildfire severity in temperate coniferous forests may depend on other conditions capable of driving extreme wildfire behavior, such as weather.

Regeneration of high-elevation five-needle pines limited by microclimate conditions across disturbance gradients

Topic: Natural areas management in light of climate change

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Background/Methods
High-elevation forests occupy environments near the physiological tolerances of tree species, and their extreme longevity have allowed for their persistence through significant climatic changes. Unprecedented climate change coupled with threats from mountain pine beetle, white pine blister rust, and changes in fire activity now threaten the resilience of these endemic forests. To improve our understanding of climate and disturbance effects on high-elevation forests dominated by limber pine (Pinus flexilis), bristlecone pine (Pinus longaeva), and whitebark pine (Pinus albicaulis), we asked: a) how does disturbance interact with water availability to influence the regenerating community?, b) to what extent is the regenerating community dominated by surviving advanced regeneration versus post-disturbance recruitment?, and c) what are the implications of species-specific responses to disturbance across climatic gradients? We evaluated natural regeneration in 70 sites varying in climatic and disturbance characteristics across eastern California and the Great Basin. Sites were either undisturbed or affected by one or more disturbance agent. We sampled community composition in addition to quantifying disturbance history and potential seed availability. We used structural equation models to evaluate direct and indirect effects of abiotic and biotic drivers on the regenerating community.
Results/Conclusions
Extensive recent mortality occurred across the study area. Natural regeneration was highly variable, with abundant regeneration of whitebark pine across varying disturbance and climatic conditions but significantly lower limber and bristlecone pine regeneration. All species showed reduced regeneration with increasing understory cover. Coarse acidic soils and decreased water deficit favored whitebark pine regeneration, while limber pine regeneration increased with increasing water deficit and tree density, suggesting potential buffering effects of tree canopy for microclimate. While increased spring snowpack and summer temperature favored bristlecone pine regeneration in undisturbed sites, these drivers had strong negative effects in burned sites.
Our findings highlight the complex drivers of regeneration in arid high-elevation pine forests. Water availability, through increased snowpack, canopy buffering, or soils, is an important driver of regeneration, and water stress is expected to increase under projected future conditions. Bird dispersal may buffer the effects of disturbance by overcoming seed limitations, however forest mortality may exacerbate microclimate conditions, leading to increasingly rare opportunities for establishment. Widespread mortality necessitates continued monitoring of natural regeneration and implications for forest persistence. This work will help managers target areas for restoration to facilitate persistence of these species under current and future climate scenarios.

Timing of moisture drives trait variation in isolated Great Basin Pinus ponderosa

Topic: Natural areas management in light of climate change

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Tessa Putz, Sarah Bisbing, Alexandra Urza

Combined effects of rising temperatures and drought are threatening forests globally. These unprecedented conditions are likely to decrease forest resilience, leading to widespread tree mortality and loss of associated forest ecosystem services. Drought adaptations may, however, confer success under these projected extreme conditions and be key to the perpetuation of long-lived tree species. Water availability varies widely across lower montane forest ecosystems of western North America, but moisture stress is characteristic of the lowest extents of these coniferous forests. The timing, amount, and type of moisture strongly influence the degree of drought adaptation in a given population, and local topographic heterogeneity may exacerbate or mitigate these effects, driving variation in trait response both within and among populations. Although drought adaptations are well-studied in widespread tree species, knowledge is limited on the extent of drought-responsive traits in disjunct conifer populations.

In the arid Basin and Range province of the western United States, Pinus ponderosa var. scopulorum is isolated to montane sky islands, making it a model system for testing the effects of climate and topography on conifer species trait variation. We sampled 57 populations across six ranges in the Great Basin and Mojave Desert to quantify trait variation in cone volume, wood density, specific leaf area, and needle lifespan. To investigate the relationship between interacting climatic and topographic conditions on drought adaptations we explored the role of seasonal climatic moisture deficit (CMD), monsoonality, and aspect on trait variation using generalized linear mixed models.

Traits varied widely both within and among populations, with timing of moisture most influential in trait response. Cone volumes increased with increasing summer CMD but decreased in areas with a heavy monsoon influence. Needle lifespan was also influenced by summer CMD and monsoonality, declining as both early summer CMD and monsoonality increased and indicating that late summer precipitation leads to earlier needle shed and reduced retention. The seasonality of moisture similarly influenced wood density, with densities increasing with increasing winter CMD, signaling the importance of winter moisture for tree growth. Only SLA was influenced by local topographic variation, where hotter, drier aspects combined with high summer CMD

Tree recruitment and forest expansion following reforestation in the Sierra Nevada, CA

Topic: Natural areas management in light of climate change

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In post-wildfire landscapes in the western Sierra Nevada, the availability of live, reproductive trees is a strong predictor of conifer regeneration. One proposed management strategy is to reforest small patches as a means of establishing future conifer seed sources in areas where high mortality from wildfire inhibits natural regeneration and where reforestation is difficult at scale. However, certain post-fire successional processes (e.g., the growth of competing vegetation) are also known to inhibit tree establishment and growth, and these processes may become dominant before planted trees become reproductive. Thus, it is unclear whether a small planted stand that produces viable seed could plausibly result in seedling establishment and forest expansion in this system.

In Summer 2019, we conducted an observational field study testing the contribution of now-reproductive planted trees relative to site characteristics in driving conifer seedling recruitment in unplanted areas. We found that regeneration was significantly higher closer to the plantations, suggesting that plantations do contribute to tree establishment outside of the planted area. We did not find a significant effect of shrub cover nor overstory cover on recruitment, leading us to reject the hypothesis that shrub cover limits recruitment even when seeds are present. Though we focused the study on areas that had high post-fire tree mortality, we still found that proximity to surviving trees was a significant predictor of recruitment. Collectively, these results suggest that plantations are a viable option for catalyzing tree recruitment in unplanted areas, but this effect may be most relevant for practitioners in areas where large, surviving trees are not available as seed sources.

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Water stress drives demographic shifts and the potential for type conversions in coastal California pine forests

Topic: Natural areas management in light of climate change

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Climate change-induced forest dieback is documented as a recent global phenomenon, with pervasive mortality having profound impacts on ecosystem services and natural forest functioning. The prolonged drought and scale of tree die-off in California from 2010-2016 (>145 million trees) was unprecedented in modern history. Morality of this magnitude can transform regional landscapes and have severe effects on forest function and ecosystem services. Ongoing drought and alteration of precipitation due to climate change will likely lead to continued mortality, which is most precarious for endemic species filling narrow yet essential ecosystem roles. Pinus radiata, an endemic to coastal California and Baja Mexico, is susceptible to non-native pine pitch canker and recently experienced widespread mortality following chronic drought stress. We used a 15-year dataset from permanent plot network to evaluate the 1) relative importance of exogenous vs. endogenous factors in shaping forest demography, 2) role of precipitation in the direction and magnitude of change, and 3) predicted impact of climate change on species persistence. Mortality peaked in during the 2014-2015 period of California's extended drought, with the greatest proportional mortality occurring in the small tree size class. Co-occurring Quercus agrifolia experienced negligible mortality over this same timeframe. For P. radiata, climatic water deficit was identified as the primary driver of mortality across all tree size classes (p

Where and when to plant trees after fire in the face of water limitation and shrub competition.

Topic: Natural areas management in light of climate change

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Wildfires in the mid-elevation forests of California's Sierra Nevada mountain range have massively increased in size and intensity over the past half-century due to a century of fire suppression and possibly climate change. Disturbance on this scale was rarely seen in the Sierra Nevada prior to the initiation of fire suppression. As a result, post-fire forest tree regeneration has become weak in many areas, leading forest managers to invest in tree planting as a strategy to hasten forest recovery after fire. Despite the critical importance of tree planting for forest recovery, it remains unclear how environmental variation in tree stress determines natural regeneration versus planting success. To address this gap, we joined efforts with the U.S. Forest Service to ask how variation in the physical environment (e.g., temperature, precipitation, light intensity, etc.) and competition from shrubs impact natural regeneration and tree planting success after forest fires throughout the Sierra Nevada. We found that natural regeneration is lowest at the hottest, driest sites and that tree planting can provide a moderate boost to forest recovery under these conditions. We also found that the timing of tree planting matters but depends on competition from shrubs. In places where shrub competition is intense, tree planting is much more successful if planting occurs the year immediately following a fire (the soonest that it is practical to plant). Alternatively, in places where shrub competition is weak, waiting a few years to plant trees until some shrubs establish actually facilitates tree survival, perhaps by providing shelter from harsh conditions. Overall, we recommend forest managers prioritize the hottest, driest sites for reforestation projects and plant trees as soon as possible where competition from shrubs will be most intense.

Natural areas management in light of climate change

Application of empirical land-cover changes to construct climate change scenarios in federally-managed lands

Topic: Natural areas management in light of climate change

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To better understand how climatic factors contribute to sagebrush-dominant ecosystems in the Great Basin, USGS researchers applied NLCD Back in Time fractional vegetation component data to measure the rate of cover change over three decades and quantified the relationship between historical climate and vegetation. Historical rates and causes of land cover change were used to create climate-land change scenarios to project how shrub, herbaceous, and bare cover may be located in the future. Historical data were used to project future rangeland cover in three different federal management areas (Beaty Butte Herd Management Area, Hart Mountain National Antelope Refuge, and Sheldon National Refuge) using a business-as-usual (BAU) scenario and RCP 8.5 climate change scenario spanning 32 years (2018-2050). Summaries of historical changes and gridded spatially-explicit map projections suggest that climate influences may make the landscape more homogeneous in the near future. Across the entire study area, 30m pixels with current high percent bare ground cover are projected to become less bare ground dominant; pixels with current moderate percent herbaceous cover are projected to contain less herbaceous cover, and pixels with current low percent shrub cover are projected to contain more shrub cover by 2050. Although change rates vary between scenarios, general patterns and composition do not differ much between scenarios by the end of the projected period. This is surprising given that RCP 8.5 climate projections suggest that minimum temperatures will be 17% higher and total precipitation will be 3% higher in the study area by 2050. Different patterns and trends are more apparent by comparing projections between management units. Hart Mountain National Antelope Refuge is projected to undergo the most change over the projected period. BAU and RCP 8.5 models project a larger decline in bare ground, as well as larger upticks in average herbaceous and shrub cover in Hart Mountain compared to the other management areas included in the study. These scenarios present alternate future outcomes that could help guide federal land managers to identify changes in cover that may affect certain species.

Burning questions: How severity of wildfire disturbance alters plant growth through disruptions of plant-soil microbiome

Topic: Natural areas management in light of climate change

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As global change accelerates in the coming decades, disturbance events are predicted to increase rapidly both in rate and intensity. As a result, much ecological research is pivoting to examine how organisms function after environmental disturbance. However, the complexity of the mechanisms of how organisms respond to disturbance is often overlooked. To assess how interactions between soil microbes and plants may influence plant response to disturbance, we a) examined soil microbial diversity of a burn severity gradient of a 2016 wildfire in Great Smoky Mountains National Park (GSMNP) and b) conducted a subsequent greenhouse experiment using soil inoculum from the GSMNP burn gradient to measure growth traits of a widespread understory species (Solidago flexicaulis, Zigzag goldenrod) in response to fire-induced changes to the soil microbiome. As previous research has found that fire generally reduces soil microbial diversity and that microbial diversity can enhance plant growth in response to environmental disturbance, we hypothesized that a) increasing burn severity reduces soil microbial diversity and b) plant growth traits are inhibited in highly disturbed soils because of low microbial diversity.

In support of our first hypothesis, soil bacterial and archaeal diversity and composition greatly differed across the burn severity gradient ($p = 0.007$). On average, unburned soils harbored 20% greater diversity of bacteria and archaea than highly burned soils. Contrary to the second hypothesis, however, the greenhouse experiment found that Solidago flexicaulis exhibited enhanced growth traits when grown in highly burned soil inoculum compared to S. flexicaulis individuals grown in unburned soil inoculum. Individuals grown in microbiomes of high burn grew nearly three times faster on average than individuals grown in microbiomes of unburned soil ($p = 0.01$). Similarly, individuals grown in microbiomes of high burn were 20% more photosynthetically active than those grown in microbiomes of unburned soil and 13% more photosynthetically active than those grown in microbiomes of low-moderately burned soil (p

Managing small natural areas in light of climate change

Topic: Natural areas management in light of climate change

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Considerable efforts have been made in recent decades to enlarge or connect many natural areas to include more complex, heterogeneous landscapes based on the premise that greater size, connectivity, and habitat diversity may allow many species to move to suitable sites as climates change. While protecting key linkages and rewilding natural habitats may be feasible strategies in some areas, in others, these options do not exist. Urban sprawl and development, conversion to farmland and production forestry, and road construction may have irrevocably severed corridors and preclude increasing the size of natural areas and surrounding habitats. This presents enormous challenges and questions regarding the long-term viability of many small, often isolated natural areas that were set aside at a time when conservation paradigms were less aware of the importance of size and connectivity in maintaining ecological functionality. In this talk, I propose an alternative for managing such sites by reconsidering their overall goals. Rather than focusing on trying to maintain unsustainable ecological functionality, I suggest that such sites might be more suitably managed as refugia or 'lifeboats' for maintaining populations of a high diversity of both rare and common species. On the continuum that describes the management of assemblages of native species, with largely untrammeled wilderness at one end and arboretums, gardens, and zoos at the other, this perspective nudges these small natural areas more forcefully towards the latter. Such a shift runs counter to how many such areas have been traditionally managed and is certain to be regarded with skepticism if not outright hostility by many. Yet, I suggest it presents a number of advantages and opportunities both for significant conservation benefits as well as for learning through experimentation. First, many species could be sustained through intensive and proactive management that is often impossible at larger scales on more extensive sites. Such practices could help sustain unique genotypes and add redundancy to populations of rare species that could serve as sources for restoring other sites as needed. Equally important, these sites could ably serve as locations for experiments with assisted migration. It is imperative that conservation practitioners begin to learn how to deliberately transport species that may be threatened in their current habitats due to changing climates and introduce them in a responsible manner to new, more suitable sites that maximizes learning opportunities. This talk will illustrate these ideas with examples from natural areas in the Pacific Northwest.