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Oregon-Washington BLM employees can access some of the papers listed below through the OSO Science Info SharePoint site at: http://teamspace/or/sites/ScienceInfo/Pages/ClimateChange.aspx.

At the end of September, the Intergovernmental Panel on Climate Change (IPCC) released the draft Physical Science Basis report as part of the fifth assessment report (AR5). The final, edited version of the report is scheduled for release in early 2014. Draft versions of the full report and individual chapters are available at http://www.ipcc.ch/.

Climate and Climate Projections

Christiansen, Bo. 2013. **Changes in Temperature Records and Extremes: Are They Statistically Significant?** Journal of Climate 26: 7863–7875. doi: http://dx.doi.org/10.1175/JCLI-D-12-00814.1

Abstract. The author investigates whether the increasing numbers of warm records and warm extremes in the extratropical Northern Hemisphere over the last decade are statistically significant. For the extremes, the focus is on summer mean temperatures; for warm records it is on daily and monthly means. Statistical significance is a highly nontrivial problem because the atmosphere is both spatially and temporally strongly autocorrelated. Therefore, a method is applied to produce an ensemble of surrogate fields that are statistically similar to the observed temperature field except that the surrogates are stationary. The significance is then estimated by comparing the number of records or extremes in the observations to similar numbers in the surrogates.

The number of warm records and the number of extreme summers are found to have the same general temporal development, with a slow decrease from the late 1940s to a minimum in the 1970s followed by an increase to the present high values. However, there is a strong difference in the statistical significance of the different quantities. With very strong statistical significance, the recent large number of warm daily records and the number of extremely warm summers cannot be explained as chance occurrences. Both of these quantities show numbers of recent consecutive years with values above the 95% level that are much larger than any similar numbers found in the ensemble of 1000 surrogates. No significant change in the number of monthly warm records is found. The statistical significance weakens when considering the individual seasons or smaller regions like Europe.

Dalelane, Clementine and Thomas Deutschländer. 2013. **A robust estimator for the intensity of the Poisson point process of extreme weather events.** Weather and Climate Extremes 1: 69-76.

Abstract. The article examines extreme temperature events defined as the exceedances of several high quantiles of temperature anomalies in regional climate model data over Germany as an example for the analysis of meteorological extremes using a two step-nonparametric approach. In the first step we estimate the intensities of the Poisson point processes of temperature extremes using a kernel estimator which so far has only rarely been used in climatology. Its advantages include robustness against model selection errors, simple computability and intuitive interpretability. In the second step we aggregate the pointwise intensity curves by means of functional cluster analysis to form regions, where the exceedance probabilities of the quantiles evolve similarly over time. A distinct gradient from Northwest to Southeast is found in the data with frequencies of exceedance of the 99% quantile of more than 1000% at the end of the 21st century compared to the control period 1961–2000.

Krasting, John P., Anthony J. Broccoli, Keith W. Dixon, and John R. Lanzante. 2013. **Future Changes in Northern Hemisphere Snowfall.** Journal of Climate 26: 7813–7828. doi: http://dx.doi.org/10.1175/JCLI-D-12-00832.1

Abstract. Using simulations performed with 18 coupled atmosphere–ocean global climate models from phase 5 of the Coupled Model Intercomparison Project (CMIP5), projections of the Northern Hemisphere snowfall under the representative concentration pathway (RCP4.5) scenario are analyzed for the period 2006–2100. These models perform well in simulating twentieth-century snowfall, although there is a positive bias in many regions. Annual snowfall is projected to decrease across much of the Northern Hemisphere during the twenty-first century, with increases projected at higher latitudes. On a seasonal basis, the transition zone between negative and positive snowfall trends corresponds approximately to the −10°C isotherm of the late twentieth-century mean surface air temperature, such that positive trends prevail in winter over large regions of Eurasia and North America. Redistributions of snowfall throughout the entire snow season are projected to occur—even in locations where there is little change in annual snowfall. Changes in the fraction of precipitation falling as snow contribute to decreases in snowfall across most Northern Hemisphere regions, while changes in total precipitation typically contribute to increases in snowfall. A signal-to-noise analysis reveals that the projected changes in snowfall, based on the RCP4.5 scenario, are likely to become apparent during the twenty-first century for most locations in the Northern Hemisphere. The snowfall signal emerges more slowly than the temperature signal, suggesting that changes in snowfall are not likely to be early indicators of regional climate change.

Shevliakova, Elena, Ronald J. Stouffer, Sergey Malyshev, John P. Krasting, George C. Hurtt, and Stephen W. Pacal. 2013. **Historical warming reduced due to enhanced land carbon uptake.** Proceedings of the National Academy of Sciences 110(42): 16730–16735.

Abstract. Previous studies have demonstrated the importance of enhanced vegetation growth under future elevated atmospheric CO_2 for 21st century climate warming. Surprisingly no study has completed an analogous assessment for the historical period, during which emissions of greenhouse gases increased rapidly and land-use changes (LUC) dramatically altered terrestrial carbon sources and sinks. Using the Geophysical Fluid Dynamics Laboratory comprehensive Earth System Model ESM2G and a reconstruction of the LUC, we estimate that enhanced vegetation growth has lowered the historical atmospheric CO_2 concentration by 85 ppm, avoiding an additional 0.31 ± 0.06 °C warming. We demonstrate that without enhanced vegetation growth the total residual terrestrial carbon flux (i.e., the net land flux minus LUC flux) would be a source of 65–82 Gt of carbon (GtC) to atmosphere instead of the historical residual carbon sink of 186–192 GtC, a carbon saving of 251–274 GtC.

Carbon and Carbon Storage

Barron-Gafford, G. A., Scott, R. L., Jenerette, G. D., Hamerlynck, E. P., and Huxman, T. E. 2013**. Landscape and environmental controls over leaf and ecosystem carbon dioxide fluxes under woody plant expansion.** Journal of Ecology 101: 1471–1483. doi: 10.1111/1365-2745.12161

Abstract. Many regions of the globe are experiencing a simultaneous change in the dominant plant functional type and regional climatology. We explored how atmospheric temperature and precipitation control leaf- and ecosystem-scale carbon fluxes within a pair of semi-arid shrublands, one upland and one riparian, that have undergone woody plant expansion.

Through a combination of leaf-level measurements on individual bunchgrasses and mesquites shrubs and ecosystem-scale monitoring using eddy covariance techniques, we sought to quantify rates of net carbon dioxide (CO_2) flux, CO_2 flux temperature sensitivity and the responsiveness of these parameters to seasonal rains and periods of soil dry-down.

We found significant differences in physiological acclimation between the two plant functional types, in that the shrubs consistently conducted photosynthesis across a broader temperature range than co-occurring grasses during dry periods, yet maximum photosynthetic rates in grasses were twice that of mesquites during the wetter monsoon season. Landscape position modulated these temperature sensitivities, as the range of functional temperatures and maximum rates of photosynthesis were two to three times greater within the riparian shrubland in dry times.

Also, it was unexpected that ecosystem-scale CO_2 uptake within both shrublands would become most temperature sensitive within the monsoon, when mesquites and grasses had their broadest range of function. This is probably explained by the changing contributions of component photosynthetic fluxes, in that the more temperature sensitive grasses, which had higher maximal rates of photosynthesis, became a larger component of the ecosystem flux.

Synthesis: Given projections of more variable precipitation and increased temperatures, it is important to understand differences in physiological activity between growth forms, as they are likely to drive patterns of ecosystem-scale CO_2 flux. As access to stable subsurface water declines with decreased precipitation, these differential patterns of temperature sensitivity among growth forms, which are dependent on connectivity to groundwater, will only become more important in determining ecosystem carbon source/sink status.

Burton, Julia I., Adrian Ares, Deanna H. Olson, and Klaus J. Puettmann. 2013. **Management trade-off between aboveground carbon storage and understory plant species richness in temperate forests.** Ecological Applications 23:1297–1310. http://dx.doi.org/10.1890/12-1472.1

Abstract. Because forest ecosystems have the capacity to store large quantities of carbon (C), there is interest in managing forests to mitigate elevated CO_2 concentrations and associated effects on the global climate. However, some mitigation techniques may contrast with management strategies for other goals, such as maintaining and restoring biodiversity. Forest thinning reduces C storage in the overstory and recruitment of detrital C. These C stores can affect environmental conditions and resource availability in the understory, driving patterns in the distribution of early and late-seral species. We examined the effects of replicated (N = 7) thinning experiments on aboveground C and understory vascular plant species richness, and we contrasted relationships between aboveground C and early- vs. late-seral species richness. Finally, we used structural equation modeling (SEM) to examine relationships among early- and late-seral species richness and live and detrital aboveground C stores.

Six years following thinning, aboveground C was greater in the high-density treatment and untreated control than in moderate- (MD) and variable-density (VD) treatments as a result of reductions in live overstory C. In contrast, all thinning treatments increased species richness relative to controls. Between the growing seasons of years 6 and 11 following treatments, the live overstory C increment tended to increase with residual density, while richness decreased in MD and VD treatments. The richness of early-seral species was negatively related to aboveground C in MD and VD, while late-seral species richness was positively (albeit weakly) related to aboveground C. Structural equation modeling analysis revealed strong negative effects of live overstory C on early-seral species richness balanced

against weaker positive effects on late-seral species richness, as well as positive effects of detrital C stocks. A trade-off between carbon and plant species richness thus emerges as a net result of these relationships among species traits, thinning treatments, and live and detrital C storage. Integrating C storage with traditional conservation objectives may require managing this trade-off within stands and landscapes (e.g., maintain early-seral habitat and species within dense, C-rich forests and, conversely, live and detrital C stores in early-seral habitats) or separating these goals across scales and species groupings.

Fernandez, Daniel P, Jason C Neff, Cho-ying Huang, Gregory P Asner and Nichole N Barger. 2013. **Twentieth century carbon stock changes related to Piñon-Juniper expansion into a black sagebrush community.** Carbon Balance and Management 8:8. doi:10.1186/1750-0680-8-8

Abstract. *Background.* Increases in the spatial extent and density of woody plants relative to herbaceous species have been observed across many ecosystems. These changes can have large effects on ecosystem carbon stocks and therefore are of interest for regional and national carbon inventories and for potential carbon sequestration or management activities. However, it is challenging to estimate the effect of woody plant encroachment on carbon because aboveground carbon stocks are very heterogeneous spatially and belowground carbon stocks exhibit complex and variable responses to changing plant cover. As a result, estimates of carbon stock changes with woody plant cover remain highly uncertain. In this study, we use a combination of plot- and remote sensing-based techniques to estimate the carbon impacts of piñon and juniper (PJ) encroachment in SE Utah across a variety of spatial scales with a specific focus on the role of spatial heterogeneity in carbon estimates.

Results. At a plot scale (300 m^2) areas piñon juniper (PJ) encroached areas had 0.26 kg C m^{-2} less understory vegetation carbon compared to un-encroached sites. This lower amount of carbon was offset by an average of 1.82 kg C m^{-2} higher carbon in PJ vegetation and 0.50 kg m^{-2} of C in PJ surface-litter carbon. Soil mineral carbon stocks were unaffected by woody plant cover and density. Aboveground carbon stocks were highly dependent on PJ vegetation density. At a 300 m^2 plot-scale, plots with low and high density of PJ forest had 1.40 kg C m^{-2} and 3.69 kg m^{-2} more carbon than the un-encroached plot. To examine how these 300 m^2 variations influence landscape scale C estimates, historical and contemporary aerial photos were analyzed to develop forest density maps in order to estimate above ground PJ associated C stock changes in a 25 ha area. This technique yielded an average estimate of 1.43 kg m^{-2} of C accumulation with PJ encroachment. Combining this estimate with analysis of tree growth increments from dendrochronologies, we estimate that these PJ stands are accumulating aboveground C at an annual rate of 0.02 kg C m^{-2} with no slowing of this rate

in healthy PJ. This result is in contrast to what has been observed in large areas of drought related PJ mortality, where C accumulation has ceased.

Conclusions. These results illustrate that the encroachment of PJ forests in SE Utah over the last century has resulted in a large (and ongoing) accumulation of carbon in PJ trees and surface litter. However, the magnitude of the increase depends to on the density of vegetation across the landscape and the health of forest stands. Both management activities that remove forest carbon and forest mortality due to drought or wildfire have the potential to quickly reverse the multi-decadal accumulation of carbon in these stands.

Hulvey, Kristin B., Richard J. Hobbs, Rachel J. Standish, David B. Lindenmayer, Lori Lach and Michael P. Perring. 2013. **Benefits of tree mixes in carbon plantings.** Nature Climate Change 3: 869-874. doi:10.1038/nclimate1862

Abstract. Increasingly governments and the private sector are using planted forests to offset carbon emissions. Few studies, however, examine how tree diversity — defined here as species richness and/or stand composition — affects carbon storage in these plantings. Using aboveground tree biomass as a proxy for carbon storage, we used meta-analysis to compare carbon storage in tree mixtures with monoculture plantings. Tree mixes stored at least as much carbon as monocultures consisting of the mixture's most productive species and at times outperformed monoculture plantings. In mixed-species stands, individual species, and in particular nitrogen-fixing trees, increased stand biomass. Further motivations for incorporating tree richness into planted forests include the contribution of diversity to total forest carbon-pool development, carbon-pool stability and the provision of extra ecosystem services. Our findings suggest a two-pronged strategy for designing carbon plantings including: (1) increased tree species richness; and (2) the addition of species that contribute to carbon storage and other target functions.

Loudermilk, E. L., Scheller, R. M., Weisberg, P. J., Yang, J., Dilts, T. E., Karam, S. L. and Skinner, C. 2013. **Carbon dynamics in the future forest: the importance of long-term successional legacy and climate–fire interactions.** Global Change Biology 19: 3502–3515. doi: 10.1111/gcb.12310

Abstract. Understanding how climate change may influence forest carbon (C) budgets requires knowledge of forest growth relationships with regional climate, long-term forest succession, and past and future disturbances, such as wildfires and timber harvesting events. We used a landscape-scale model of forest succession, wildfire, and C dynamics (LANDIS-II) to evaluate the effects of a changing climate (A2 and B1 IPCC emissions; Geophysical Fluid Dynamics Laboratory General Circulation Models) on total forest C, tree species composition, and wildfire dynamics in the Lake Tahoe Basin, California, and Nevada. The independent effects of temperature and precipitation were assessed within and among climate models. Results highlight the importance of modeling forest succession and stand development processes at the landscape scale for understanding the C cycle. Due primarily to landscape legacy effects of historic logging of the Comstock Era in the late 1880s, C sequestration may continue throughout the current century, and the forest will remain a C sink (Net Ecosystem Carbon Balance > 0), regardless of climate regime. Climate change caused increases in temperatures limited simulated C sequestration potential because of augmented fire activity and reduced establishment ability of subalpine and upper montane trees. Higher temperatures influenced forest response more than reduced precipitation. As the forest reached its potential steady state, the forest could become C neutral or a C source, and climate change could accelerate this transition. The future of forest ecosystem C cycling in many forested systems worldwide may depend more on major disturbances and landscape legacies related to land use than on projected climate change alone.

Man, Cosmin D., Kevin C. Lyons, John D. Nelson, and Gary Q. Bull. 2013. **Potential of alternate forest management practices to sequester and store Carbon in two forest estates in British Columbia, Canada.** Forest Ecology and Management 305: 239-247.

Abstract. This paper uses the inventory of two different actively managed forest estates located on the Coast and Interior forest regions in British Columbia to analyze the potential of alternate forest management practices to sequester and store Carbon while achieving a range of management objectives. Strategies that increase growth rates (fertilization and the use of genetically improved growing stock) and a fixed reduction in the harvest level were analyzed to determine the magnitude of the difference in terms of stored Carbon. The performance of the harvest reduction strategies (fixed harvest level, increased rotation age, and increased area in reserves) was analyzed in more detail to determine if there is a reason for the forest manager to favor one of these strategies over the others, and whether this choice is the same for both forests considered in this paper. Strategies that reduce harvest levels stored significantly more Carbon over the 100-year planning horizon as compared to strategies that increase growth rates. For both forest estates, little difference was observed between the harvest reduction strategies (less than 4.1% over 100 years). However, the fixed harvest level strategy allows the forest manager to shift the harvesting to various areas in order to respond to an uncertain future while accommodating the various management objectives of the forest estate.

Nabuurs, Gert-Jan, Marcus Lindner, Pieter J. Verkerk, Katja Gunia, Paola Deda, Roman Michalak and Giacomo Grassi. 2013. **First signs of carbon sink saturation in European forest biomass.** Nature Climate Change 3: 792–796. doi:10.1038/nclimate1853

Abstract. European forests are seen as a clear example of vegetation rebound in the Northern Hemisphere; recovering in area and growing stock since the 1950s, after centuries of stock decline and deforestation. These regrowing forests have shown to be a persistent carbon sink, projected to continue for decades, however, there are early signs of saturation. Forest policies and management strategies need revision if we want to sustain the sink.

Restaino, Joseph C. and David L. Peterson. 2013. **Wildfire and fuel treatment effects on forest carbon dynamics in the western United States**. Forest Ecology and Management 303: 46-60.

Abstract. Sequestration of carbon (C) in forests has the potential to mitigate the effects of climate change by offsetting future emissions of greenhouse gases. However, in dry temperate forests, wildfire is a natural disturbance agent with the potential to release large fluxes of C into the atmosphere. Climate-driven increases in wildfire extent and severity are expected to increase the risks of reversal to C stores and affect the potential of dry forests to sequester C. In the western United States, fuel treatments that successfully reduce surface fuels in dry forests can mitigate the spread and severity of wildfire, while reducing both tree mortality and emissions from wildfire. However, heterogeneous burn environments, site-specific variability in post-fire ecosystem response, and uncertainty in future fire frequency and extent complicate assessments of long-term (decades to centuries) C dynamics across large landscapes. Results of studies on the effects of fuel treatments and wildfires on long-term C retention across large landscapes are limited and equivocal. Stand-scale studies, empirical and modeled, describe a wide range of total treatment costs (12–116 Mg C ha^{-1}) and reductions in wildfire emissions between treated and untreated stands (1–40 Mg C ha^{-1}). Conclusions suggest the direction (source, sink) and magnitude of net C effects from fuel treatments are similarly variable (−33 Mg C ha^{-1} to +3 Mg C ha^{-1}). Studies at large spatial and temporal scales suggest that there is a low likelihood of high-severity wildfire events interacting with treated forests, negating any expected C benefit from fuels reduction. The frequency, extent, and severity of wildfire are expected to increase as a result of changing climate, and additional information on C response to management and disturbance scenarios is needed improve the accuracy and usefulness of assessments of fuel treatment and wildfire effects on C dynamics.

Smith, James E., Linda S. Heath, and Coeli M. Hoover. 2013. **Carbon factors and models for forest carbon estimates for the 2005–2011 National Greenhouse Gas Inventories of the United States.** Forest Ecology and Management 307: 7-19.

Abstract. Most nations have ratified the United Nations Framework Convention on Climate Change, and are mandated to report National Greenhouse Gas Inventories, including the land use, land use change and forestry sector when it is significant. Participating countries commonly use data from national forest inventories as a basis for their forest-related emissions estimates. The estimates are required to be consistent, comparable among parties, transparent, and well-documented. To help meet these requirements, we describe the data and methods used to calculate the forest carbon component of the United States' greenhouse gas emissions and sinks which we provided to the US Environmental Protection Agency to be compiled for the submission years 2005–2011. Past forest inventories were not designed to measure or take samples of data directly related to quantifying ecosystem carbon stocks necessary for greenhouse gas reporting. This study provides information used to bridge that gap and enable harmonized reporting. Specifically, we provide the forest inventory plot-data-to-carbon-stock conversion factors and associated uncertainty bounds in use for the reporting years prior to the availability of more directly measured or sampled carbon stocks. The factors are similar to default values supplied by the Intergovernmental Panel on Climate Change and current scientific literature. Overall, this approach indicates that forest ecosystems of the United States sequester approximately 170 Tg of carbon per year, which represents a net annual increase of half a percent of forest carbon stocks.

Woodall, C.W., B.F. Walters, S.N. Oswalt, G.M. Domke, C. Toney, and A.N. Gray. 2013. **Biomass and carbon attributes of downed woody materials in forests of the United States.** Forest Ecology and Management 305: 48-59.

Abstract. Due to burgeoning interest in the biomass/carbon attributes of forest downed and dead woody materials (DWMs) attributable to its fundamental role in the carbon cycle, stand structure/diversity, bioenergy resources, and fuel loadings, the U.S. Department of Agriculture has conducted a nationwide field-based inventory of DWM. Using the national DWM inventory, attributes (e.g., carbon stock totals and biomass density) were summarized by state and common tree species along with evaluations of residue pile metrics and relationships between DWM and other stand attributes (e.g., live tree biomass, relative density, and climate). Results indicate that DWM are ubiquitous in US forests with individual components (e.g., fine woody debris and piles) varying by region as influenced by endemic ecosystem dynamics and management practices. Eastern forests, particularly in the southeast, have fine woody debris and residue piles biomass densities that often exceed those of west coast forests. Rocky Mountain forests have coarse woody biomass densities approaching those of

west coast forests, which have the largest amounts nationally. There is a complex relationship between the standing dead, standing live, and down dead wood biomass densities per unit area in the context of changing stand relative densities and average annual precipitation/minimum temperatures. As evidenced by this initial exploration, a publicly available national dataset comprised of DWM attributes may inform decision makers with objective estimates of DWM resources and facilitate further DWM dynamics research.

Phenology Changes

Kudo, Gaku and Takashi Y. Ida. 2013. **Early onset of spring increases the phenological mismatch between plants and pollinators.** Ecology 94:2311–2320. http://dx.doi.org/10.1890/12-2003.1

Abstract. Climate warming accelerates the timing of flowering and insect pollinator emergence, especially in spring. If these phenological shifts progress independently between species, features of plant–pollinator mutualisms may be modified. However, evidence of phenological mismatch in pollination systems is limited. We investigated the phenologies of a spring ephemeral, Corydalis ambigua, and its pollinators (bumble bees), and seed-set success over 10–14 years in three populations. Although both flowering onset and first detection of overwintered queen bees in the C. ambigua populations were closely related to snowmelt time and/or spring temperature, flowering tended to be ahead of first pollinator detection when spring came early, resulting in lower seed production owing to low pollination service. Relationships between flowering onset time, phenological mismatch, and seed-set success strongly suggest that phenological mismatch is a major limiting factor for reproduction of spring ephemerals. This report demonstrates the mechanism of phenological mismatch and its ecological impact on plant–pollinator interactions based on long-term monitoring. Frequent occurrence of mismatch can decrease seed production and may affect the population dynamics of spring ephemerals.

Species Range Changes

Bertelsmeier, Cleo, Gloria M. Luque, and Franck Courchamp. 2013. **The impact of climate change changes over time.** Biological Conservation 167: 107-115.

Abstract. Species distribution models (SDMs) have become an important tool to predict the impact of climate change on the distribution of a given species. Generally, projections for a chosen time horizon in the future are compared with the size of the species' current distribution. In this study, we show that selection of the target time horizon can qualitatively alter the prediction of a species' future distribution. We illustrate this by assessing the potential distribution of 15 invasive ant species in 2020, 2050 and 2080 at a global scale. Our results indicate that for 6 out of the 15 species modelled, the trend of potential habitat size (i.e., decrease or increase) changed over time following climate change. In four species, the sign of the trend changed, from an initial expansion to a subsequent reduction or vice versa, depending on the date projected to. In some cases, these changes were great (e.g., from an initial increase of 36.5% in 2050 to a decrease of −64.3% in 2080). Our findings stress the importance of using several projection horizons to avoid misled species management decisions.

Caplat, P., Cheptou, P.-O., Diez, J., Guisan, A., Larson, B. M. H., Macdougall, A. S., Peltzer, D. A., Richardson, D. M., Shea, K., van Kleunen, M., Zhang, R. and Buckley, Y. M. 2013. **Movement, impacts and management of plant distributions in response to climate change: insights from invasions.** Oikos 122: 1265–1274. doi: 10.1111/j.1600-0706.2013.00430.x

Abstract. Prediction and management of species responses to climate change is an urgent but relatively young research field. Therefore, climate change ecology must by necessity borrow from other fields. Invasion ecology is particularly well-suited to informing climate change ecology because both invasion ecology and climate change ecology address the trajectories of rapidly changing novel systems. Here we outline the broad range of active research questions in climate change ecology where research from invasion ecology can stimulate advances. We present ideas for how concepts, case-studies and methodology from invasion ecology can be adapted to improve prediction and management of species responses to climate change.

A major challenge in this era of rapid climate change is to predict changes in species distributions and their impacts on ecosystems, and, if necessary, to recommend management strategies for maintenance of biodiversity or ecosystem services. Biological invasions, studied in most biomes of the world, can provide useful analogs for some of the ecological consequences of species distribution shifts in response to climate change. Invasions illustrate the adaptive and interactive responses that can occur when species are confronted with new environmental conditions. Invasion ecology complements climate change research and provides insights into the following questions: 1) how will species distributions respond to climate change? 2) how will species movement affect recipient ecosystems? And 3) should we, and if so how can we, manage species and ecosystems in the face of climate change? Invasion ecology demonstrates that a trait-based approach can help to predict spread speeds and impacts on ecosystems, and has the potential to predict climate change impacts on species ranges and recipient ecosystems. However, there is a need to analyse traits in the context of life-history and demography, the stage in the colonisation process (e.g. spread, establishment or impact), the distribution of suitable habitats in the landscape, and the novel abiotic and biotic conditions under which those

traits are expressed. As is the case with climate change, invasion ecology is embedded within complex societal goals. Both disciplines converge on similar questions of 'when to intervene?' and 'what to do?' which call for a better understanding of the ecological processes and social values associated with changing ecosystems.

Delattre, T., Baguette, M., Burel, F., Stevens, V. M., Quénol, H. and Vernon, P. 2013. **Interactive effects of landscape and weather on dispersal.** Oikos 122: 1576–1585. doi: 10.1111/j.1600-0706.2013.00123.x

Abstract. Over the last decades, many species have been forced to track their shifting climate envelopes, and at the same time man-induced landscape fragmentation has led to the global decrease of natural habitat availability and connectivity. The interaction between these two co-occurring global environmental changes might have very strong effects on biodiversity that are still understudied. Species-specific responses to these environmental changes critically depend on individual dispersal, either to track suitable climatic conditions or to cope with landscape fragmentation. Here we study how dispersal in an ectotherm is affected by interactions between landscape fragmentation and weather conditions. We show that both the emigration rates out of suitable habitats and the topology of the trajectory of dispersing individuals were affected by temperature and landscape fragmentation. The emigration rate was temperature-dependent in fragmented landscapes, with butterflies emigrating more at high temperatures. The emigration rate was temperature insensitive in more continuous landscapes. Move length was farther at low temperatures and less at high temperatures in fragmented landscapes. Move length was less at low temperatures and farther at high temperatures in more continuous landscapes. To our knowledge only two recent studies have documented patterns of interactions between climate and fragmentation, despite the fact that they are the two main drivers of biodiversity loss worldwide. Here, we go a step further by providing mechanistic explanations to such patterns.

Pfeifer-Meister, Laurel, Scott D. Bridgham, Chelsea J. Little, Lorien L. Reynolds, Maya E. Goklany, and Bart R. Johnson. 2013. **Pushing the limit: experimental evidence of climate effects on plant range distributions.** Ecology 94:2131–2137. http://dx.doi.org/10.1890/13-0284.1

Abstract. Whether species will be extirpated in their current geographic ranges due to rapidly changing climate, and if so, whether they can avoid extinction by shifting their distributions are pressing questions for biodiversity conservation. However, forecasts of climate change impacts on species' geographic distributions rarely incorporate a demographic understanding of species' responses to climate. Because many biotic and abiotic factors at multiple scales control species' range limits,

experimentation is essential to establish underlying mechanisms. We used a manipulative climate change experiment embedded within a natural climate gradient to examine demographic responses of 12 prairie species with northern range limits within the Pacific Northwest, USA. During the first year, warming decreased recruitment of species even at the coolest edge of their current ranges, but this effect disappeared when they were moved poleward beyond their current ranges. This response was largely driven by differences in germination rates. Other vital rates responded in unique and sometimes opposing ways (survivorship vs. fitness) to species' current ranges and climate change, and were mediated by indirect effects of climate on competition and nutrient availability. Our results demonstrate the importance of using regional-scale climate manipulations and the need for longer-term experiments on the demographic responses that control species' distributions.

Travis, J. M. J., Delgado, M., Bocedi, G., Baguette, M., Bartoń, K., Bonte, D., Boulangeat, I., Hodgson, J. A., Kubisch, A., Penteriani, V., Saastamoinen, M., Stevens, V. M. and Bullock, J. M. 2013. **Dispersal and species' responses to climate change.** Oikos 122: 1532–1540. doi: 10.1111/j.1600-0706.2013.00399.x

Abstract. Dispersal is fundamental in determining biodiversity responses to rapid climate change, but recently acquired ecological and evolutionary knowledge is seldom accounted for in either predictive methods or conservation planning. We emphasise the accumulating evidence for direct and indirect impacts of climate change on dispersal. Additionally, evolutionary theory predicts increases in dispersal at expanding range margins, and this has been observed in a number of species. This multitude of ecological and evolutionary processes is likely to lead to complex responses of dispersal to climate change. As a result, improvement of models of species' range changes will require greater realism in the representation of dispersal. Placing dispersal at the heart of our thinking will facilitate development of conservation strategies that are resilient to climate change, including landscape management and assisted colonisation.

Synthesis. This article seeks synthesis across the fields of dispersal ecology and evolution, species distribution modelling and conservation biology. Increasing effort focuses on understanding how dispersal influences species' responses to climate change. Importantly, though perhaps not broadly widely-recognised, species' dispersal characteristics are themselves likely to alter during rapid climate change. We compile evidence for direct and indirect influences that climate change may have on dispersal, some ecological and others evolutionary. We emphasise the need for predictive modelling to account for this dispersal realism and highlight the need for conservation to make better use of our existing knowledge related to dispersal.

Biodiversity

De Frennea, Pieter, Francisco Rodríguez-Sánchez, David Anthony Coomes, Lander Baeten, Gorik Verstraeten, Mark Vellend, Markus Bernhardt-Römermann, Carissa D. Brown, Jörg Brunet, Johnny Cornelis, Guillaume M. Decocq, Hartmut Dierschke, Ove Eriksson, Frank S. Gilliam, Radim Hédl, Thilo Heinken, Martin Hermy, Patrick Hommel, Michael A. Jenkins, Daniel L. Kelly, Keith J. Kirby, Fraser J. G. Mitchell, Tobias Naaf, Miles Newman, George Peterken, Petr Petřík, Jan Schultz, Grégory Sonnier, Hans Van Calster, Donald M. Waller, Gian-Reto Walther, Peter S. White, Kerry D. Woods, Monika Wulf, Bente Jessen Graae, and Kris Verheyen. 2013. **Microclimate moderates plant responses to macroclimate warming.** Proceedings of the National Academy of Sciences 110(46): 18561-18565.

Abstract. Recent global warming is acting across marine, freshwater, and terrestrial ecosystems to favor species adapted to warmer conditions and/or reduce the abundance of cold-adapted organisms (i.e., "thermophilization" of communities). Lack of community responses to increased temperature, however, has also been reported for several taxa and regions, suggesting that "climatic lags" may be frequent. Here we show that microclimatic effects brought about by forest canopy closure can buffer biotic responses to macroclimate warming, thus explaining an apparent climatic lag. Using data from 1,409 vegetation plots in European and North American temperate forests, each surveyed at least twice over an interval of 12–67 y, we document significant thermophilization of ground-layer plant communities. These changes reflect concurrent declines in species adapted to cooler conditions and increases in species adapted to warmer conditions. However, thermophilization, particularly the increase of warm-adapted species, is attenuated in forests whose canopies have become denser, probably reflecting cooler growing-season ground temperatures via increased shading. As standing stocks of trees have increased in many temperate forests in recent decades, local microclimatic effects may commonly be moderating the impacts of macroclimate warming on forest understories. Conversely, increases in harvesting woody biomass—e.g., for bioenergy—may open forest canopies and accelerate thermophilization of temperate forest biodiversity.

Grimm, Nancy B, F Stuart Chapin III, Britta Bierwagen, Patrick Gonzalez, Peter M Groffman, Yiqi Luo, Forrest Melton, Knute Nadelhoffer, Amber Pairis, Peter A Raymond, Josh Schimel, and Craig E Williamson. 2013. **The impacts of climate change on ecosystem structure and function.** Frontiers in Ecology and the Environment 11: 474–482. http://dx.doi.org/10.1890/120282

Abstract. Recent climate-change research largely confirms the impacts on US ecosystems identified in the 2009 National Climate Assessment and provides greater mechanistic understanding and geographic specificity for those impacts. Pervasive climate-change impacts on ecosystems are those

that affect productivity of ecosystems or their ability to process chemical elements. Loss of sea ice, rapid warming, and higher organic inputs affect marine and lake productivity, while combined impacts of wildfire and insect outbreaks decrease forest productivity, mostly in the arid and semi-arid West. Forests in wetter regions are more productive owing to warming. Shifts in species ranges are so extensive that by 2100 they may alter biome composition across 5–20% of US land area. Accelerated losses of nutrients from terrestrial ecosystems to receiving waters are caused by both winter warming and intensification of the hydrologic cycle. Ecosystem feedbacks, especially those associated with release of carbon dioxide and methane release from wetlands and thawing permafrost soils, magnify the rate of climate change.

Soudzilovskaia, Nadejda A., Tatiana G. Elumeeva, Vladimir G. Onipchenko, Islam I. Shidakov, Fatima S. Salpagarova, Anzor B. Khubiev, Dzhamal K. Tekeev, and Johannes H. C. Cornelissen. 2013. **Functional traits predict relationship between plant abundance dynamic and long-term climate warming.** Proceedings of the National Academy of Sciences 110(45): 18100-18184.

Abstract. Predicting climate change impact on ecosystem structure and services is one of the most important challenges in ecology. Until now, plant species response to climate change has been described at the level of fixed plant functional types, an approach limited by its inflexibility as there is much interspecific functional variation within plant functional types. Considering a plant species as a set of functional traits greatly increases our possibilities for analysis of ecosystem functioning and carbon and nutrient fluxes associated therewith. Moreover, recently assembled large-scale databases hold comprehensive per-species data on plant functional traits, allowing a detailed functional description of many plant communities on Earth. Here, we show that plant functional traits can be used as predictors of vegetation response to climate warming, accounting in our test ecosystem (the species-rich alpine belt of Caucasus Mountains, Russia) for 59% of variability in the per-species abundance relation to temperature. In this mountain belt, traits that promote conservative leaf water economy (higher leaf mass per area, thicker leaves) and large investments in belowground reserves to support next year's shoot buds (root carbon content) were the best predictors of the species increase in abundance along with temperature increase. This finding demonstrates that plant functional traits constitute a highly useful concept for forecasting changes in plant communities, and their associated ecosystem services, in response to climate change.

Staudinger, Michelle D, Shawn L Carter, Molly S Cross, Natalie S Dubois, J Emmett Duffy, Carolyn Enquist, Roger Griffis, Jessica J Hellmann, Joshua J Lawler, John O'Leary, Scott A Morrison, Lesley Sneddon, Bruce A Stein, Laura M Thompson, and Woody Turner. 2013. **Biodiversity in a changing climate: a synthesis of current and projected trends in the US.** Frontiers in Ecology and the Environment 11: 465–473. http://dx.doi.org/10.1890/120272

Abstract. This paper provides a synthesis of the recent literature describing how global biodiversity is being affected by climate change and is projected to respond in the future. Current studies reinforce earlier findings of major climate-change-related impacts on biological systems and document new, more subtle after-effects. For example, many species are shifting their distributions and phenologies at faster rates than were recorded just a few years ago; however, responses are not uniform across species. Shifts have been idiosyncratic and in some cases counterintuitive, promoting new community compositions and altering biotic interactions. Although genetic diversity enhances species' potential to respond to variable conditions, climate change may outpace intrinsic adaptive capacities and increase the relative vulnerabilities of many organisms. Developing effective adaptation strategies for biodiversity conservation will not only require flexible decision-making and management approaches that account for uncertainties in climate projections and ecological responses but will also necessitate coordinated monitoring efforts.

Staudt, Amanda, Allison K Leidner, Jennifer Howard, Kate A Brauman, Jeffrey S Dukes, Lara J Hansen, Craig Paukert, John Sabo, and Luis A Solórzano. 2013. **The added complications of climate change: understanding and managing biodiversity and ecosystems.** Frontiers in Ecology and the Environment 11: 494–501. http://dx.doi.org/10.1890/120275

Abstract. Ecosystems around the world are already threatened by land-use and land-cover change, extraction of natural resources, biological disturbances, and pollution. These environmental stressors have been the primary source of ecosystem degradation to date, and climate change is now exacerbating some of their effects. Ecosystems already under stress are likely to have more rapid and acute reactions to climate change; it is therefore useful to understand how multiple stresses will interact, especially as the magnitude of climate change increases. Understanding these interactions could be critically important in the design of climate adaptation strategies, especially because actions taken by other sectors (eg energy, agriculture, transportation) to address climate change may create new ecosystem stresses.

Forest Vegetation

Fernandez-Going, B. M., S. P. Harrison, B. L. Anacker, and H. D. Safford. 2013. **Climate interacts with soil to produce beta diversity in Californian plant communities.** Ecology 94:2007–2018. http://dx.doi.org/10.1890/12-2011.1

Abstract. Spatially distinct communities can arise through interactions and feedbacks between abiotic and biotic factors. We suggest that, for plants, patches of infertile soils such as serpentine may support more distinct communities from those in the surrounding non-serpentine matrix in regions where the climate is more productive (i.e., warmer and/or wetter). Where both soil fertility and climatic productivity are high, communities may be dominated by plants with fast-growing functional traits, whereas where either soils or climate impose low productivity, species with stress-tolerant functional traits may predominate. As a result, both species and functional composition may show higher dissimilarity between patch and matrix in productive climates. This pattern may be reinforced by positive feedbacks, in which higher plant growth under favorable climate and soil conditions leads to higher soil fertility, further enhancing plant growth.

For 96 pairs of sites across a 200-km latitudinal gradient in California, we found that the species and functional dissimilarities between communities on infertile serpentine and fertile non-serpentine soils were higher in more productive (wetter) regions. Woody species had more stress-tolerant functional traits on serpentine than non-serpentine soil, and as rainfall increased, woody species functional composition changed toward fast-growing traits on non-serpentine, but not on serpentine soils. Soil organic matter increased with rainfall, but only on non-serpentine soils, and the difference in organic matter between soils was positively correlated with plant community dissimilarity. These results illustrate a novel mechanism wherein climatic productivity is associated with higher species, functional, and landscape-level dissimilarity (beta diversity).

Magruder, Matthew, Sophan Chhin, Brian Palik, and John B. Bradford. 2013. **Thinning increases climatic resilience of red pine.** Canadian Journal of Forest Research 43(9): 878-889. 10.1139/cjfr-2013-0088

Abstract. Forest management techniques such as intermediate stand-tending practices (e.g., thinning) can promote climatic resiliency in forest stands by moderating tree competition. Residual trees gain increased access to environmental resources (i.e., soil moisture, light), which in turn has the potential to buffer trees from stressful climatic conditions. The influences of climate (temperature and precipitation) and forest management (thinning method and intensity) on the productivity of red pine (*Pinus resinosa* Ait.) in Michigan were examined to assess whether repeated thinning treatments were able to increase climatic resiliency (i.e., maintaining productivity and reduced sensitivity to climatic stress). The cumulative productivity of each thinning treatment was determined, and it was found that thinning from

below to a residual basal area of 14 $m^2 \cdot ha^{-1}$ produced the largest average tree size but also the second lowest overall biomass per acre. On the other hand, the uncut control and the thinning from above to a residual basal area of 28 $m^2 \cdot ha^{-1}$ produced the smallest average tree size but also the greatest overall biomass per acre. Dendrochronological methods were used to quantify sensitivity of annual radial growth to monthly and seasonal climatic factors for each thinning treatment type. Climatic sensitivity was influenced by thinning method (i.e., thinning from below decreased sensitivity to climatic stress more than thinning from above) and by thinning intensity (i.e., more intense thinning led to a lower climatic sensitivity). Overall, thinning from below to a residual basal area of 21 $m^2 \cdot ha^{-1}$ represented a potentially beneficial compromise to maximize tree size, biomass per acre, and reduced sensitivity to climatic stress, and, thus, the highest level of climatic resilience.

Metz, Margaret R., J. Morgan Varner, Kerri M. Frangioso, Ross K. Meentemeyer, and David M. Rizzo. 2013. **Unexpected redwood mortality from synergies between wildfire and an emerging infectious disease.** Ecology 94:2152–2159. http://dx.doi.org/10.1890/13-0915.1

Abstract. An under-examined component of global change is the alteration of disturbance regimes due to warming climates, continued species invasions, and accelerated land-use change. These drivers of global change are themselves novel ecosystem disturbances that may interact with historically occurring disturbances in complex ways. Here we use the natural experiment presented by wildfires in redwood forests impacted by an emerging infectious disease to demonstrate unexpected synergies of novel disturbance interactions. The dominant tree, coast redwood (fire resistant without negative disease impacts), experienced unexpected synergistic increases in mortality when fire and disease co-occurred. The increased mortality risk, more than fourfold at the peak of the effect, was not predictable from impacts of either disturbance alone. Changes in fire behavior associated with changes to forest fuels that occurred through disease progression overwhelmed redwood's usual resilience to wildfire. Our results demonstrate the potential for interacting disturbances to initiate novel successional trajectories and compromise ecosystem resilience.

Stahl, Ulrike, Jens Kattge, Björn Reu, Winfried Voigt, Kiona Ogle, John Dickie, and Christian Wirth. 2013. **Whole-plant trait spectra of North American woody plant species reflect fundamental ecological strategies.** Ecosphere 4:art128. http://dx.doi.org/10.1890/ES13-00143.1

Abstract. The adaptation of plant species to their biotic and abiotic environment is manifested in their traits. Suites of correlated functional traits may reflect fundamental tradeoffs and general plant strategies and hence

represent trait spectra along which plant species can vary according to their respective strategies. However, the functional interpretation of these trait spectra requires the inspection of their relation to plant performance. We employed principle coordinate analysis (PCoA) to quantify fundamental whole-plant trait spectra based on 23 traits for 305 North American woody species that span boreal to subtropical climates. We related the major axes of PCoA to five measures of plant performance (i.e., growth rate, and tolerance to drought, shade, water-logging and fire) for all species and separately for gymnosperms and angiosperms. Across all species a unified gymnosperm-angiosperm trait spectrum (wood density, seed mass, rooting habit) is identified, which is correlated with drought tolerance. Apart from this, leaf type and specific leaf area (SLA) strongly separate gymnosperms from angiosperms. For gymnosperms, one trait spectrum emerges (seed mass, rooting habit), which is positively correlated with drought tolerance and inversely with shade tolerance, reflecting a tradeoff between these two strategies due to opposing trait characteristics. Angiosperms are functionally more diverse. The trait spectra related to drought tolerance and shade tolerance are decoupled and three distinct strategies emerge: high drought tolerance (low SLA, dense wood, heavy seeds, taproot), high shade tolerance (high SLA, shallow roots, high toxicity, opposite arranged leaves), and fast growth/stress intolerance (large maximum heights, soft wood, light seeds, high seed spread rate). In summary, our approach reveals that complex suits of traits and potential tradeoffs underlie fundamental performance strategies in forests. Studies relying on small sets of plant traits may not be able to reveal such underlying strategies.

von Arx, G., Graf Pannatier, E., Thimonier, A., and Rebetez, M. 2013. **Microclimate in forests with varying leaf area index and soil moisture: potential implications for seedling establishment in a changing climate.** Journal of Ecology 101: 1201–1213. doi: 10.1111/1365-2745.12121

Abstract. Forest microclimate is crucial for the growth and survival of tree seedlings and understorey vegetation. This high ecological relevance contrasts with the poor functional and quantitative understanding of how the properties of forest ecosystems influence forest microclimate.

In a long-term (1998–2011) trial, we investigated how temporal patterns of microclimate below sparse and dense forest canopy related to those of nearby open areas and how this relationship was influenced by soil moisture and seasonality. Air temperature (*T*), vapour pressure deficit (VPD), soil matrix potential and leaf area index (LAI) were measured in a unique set-up of below-canopy and open-area meteorological stations at eleven distinct forest ecosystems, characteristic of subalpine and temperate climate zones. Data from these plots were analysed for the moderating capacity of the canopy, that is, the differences between below-canopy and open-area microclimate, with respect to (i) long-term means, (ii) dynamics within homogeneous moist- vs. dry-soil periods and (iii) diurnal patterns.

The long-term mean moderating capacity of the canopy was up to 3.3 °C for daily T_{max} and 0.52 kPa for daily VPD_{max}, of which soil moisture status alone accounted for up to 1.2 °C (T_{max}) and 0.21 kPa (VPD_{max}). Below dense canopy (LAI > 4), the moderating capacity was generally higher when soils were dry and increased during dry-soil periods, particularly in spring and somewhat less in summer. The opposite pattern was found below sparse canopy (LAI < 4). At the diurnal level, moderating capacity below dense canopy was strongest in mid-afternoon and during dry-soil conditions, whereas peak moderation below sparse canopy occurred in mid-morning and during moist-soil conditions.

Synthesis. Our results suggest a threshold canopy density, which is probably linked to site-specific water availability, below which the moderating capacity of forest ecosystems switches from supportive to unsupportive for seedling establishment. Under supportive moderating capacity, we understand a stronger mitigation during physiologically most demanding conditions for plant growth. Such a threshold canopy density sheds new light on forest resilience to climate change. Climate change may alter forest canopy density in a way that precludes successful establishment of tree species and ultimately changes forest ecosystem structure and functioning.

Rangeland Vegetation

Concilio, A. L. and Loik, M. E. 2013. **Elevated nitrogen effects on *Bromus tectorum* dominance and native plant diversity in an arid montane ecosystem.** Applied Vegetation Science 16: 598–609. doi: 10.1111/avsc.12029

Abstract. *Questions.* Dominance of the widespread fire-altering invasive grass, *Bromus tectorum,* is markedly reduced at upper elevations in the Great Basin Desert. Here, we evaluated whether increased anthropogenic nitrogen (N) deposition would have an effect on species composition and ecosystem invasibility by *B. tectorum* at high elevations, and whether *B. tectorum* cover was associated with decreased native plant diversity.

Location. Sagebrush steppe of the eastern Sierra Nevada, CA, US, at the western edge of the Great Basin Desert.

Methods. We set up 54 paired plots, half of which were exposed to elevated N deposition (50 $kg \cdot ha^{-1} \cdot yr^{-1}$ at the time of snowmelt for 4 yr) and half acted as controls, in areas differing in disturbance history (grazed, burned and grazed–burned). We monitored species composition each summer from 2008 to 2011 and then compared species richness, Shannon's diversity (H'), Simpson's dominance (D'), Simpson's evenness ($E_{1/D}$), *B. tectorum* dominance and community similarity (with ANOSIM and SIMPER analyses) by N treatment and disturbance history.

Results. Species composition differed by disturbance history in all years (ANOSIM, $P < 0.05$), and the grazed–burned plots consistently had the highest levels of *B. tectorum* dominance ($P \leq 0.0003$) and cover ($P \leq 0.0001$). *Bromus tectorum* cover was inversely related to native forb species richness ($r = -0.44$, $P < 0.0001$), H'($r_s = -0.73$, $P < 0.0001$), -ln(D') ($r_s = -0.75$, $P < 0.0001$) and $E_{1/D}'$($r_s = -0.49$, $P < 0.0001$). We found no evidence that increased N deposition would affect native plant diversity after 4 yr in this arid montane ecosystem, but the possibility of longer-term effects cannot be eliminated.

Conclusions. Results suggest that high-elevation plant communities are already experiencing invasion impacts even though changes to the fire cycle have not yet occurred. In the most disturbed areas, *B. tectorum* cover is approaching the threshold for increased fire risk, which could result in more severe impacts at high elevations.

Kulmatiski, Andrew and Karen H. Beard. 2013. **Woody plant encroachment facilitated by increased precipitation intensity.** Nature Climate Change 3: 833–837. doi:10.1038/nclimate1904

Abstract. Global circulation models and empirical evidence suggest that precipitation events are likely to become more extreme across much of the globe. As most plant roots are in shallow soils, small but pervasive changes in precipitation intensity could be expected to cause large-scale shifts in plant growth, yet experimental tests of the effects of precipitation intensity are lacking. Here we show that, without changing the total amount of precipitation, small experimental increases in precipitation intensity can push soil water deeper into the soil, increase aboveground woody plant growth and decrease aboveground grass growth in a savannah system. These responses seemed to reflect the ability of woody plants to increase their rooting depths and competitively suppress grass growth. In many parts of the world, woody plant abundance has multiplied in the past 50–100 years, causing changes in fire, forage value, biodiversity and carbon cycling. Factors such as fire, grazing and atmospheric CO_2 concentrations have become dominant explanations for this woody encroachment and semi-arid structure in general. Our results suggest that niche partitioning is also an important factor in tree–grass coexistence and that the woody plant encroachment observed over the past century may continue in the future should precipitation intensity increase.

Polley, H. Wayne, David D. Briske, Jack A. Morgan, Klaus Wolter, Derek W. Bailey, and Joel R. Brown. 2013. **Climate Change and North American Rangelands: Trends, Projections, and Implications.** Rangeland Ecology and Management 66(5): 493–511.

Abstract. The amplified "greenhouse effect" associated with increasing concentrations of greenhouse gases has increased atmospheric temperature by 1°C since industrialization (around 1750), and it is anticipated to cause an

additional 2°C increase by mid-century. Increased biospheric warming is also projected to modify the amount and distribution of annual precipitation and increase the occurrence of both drought and heat waves. The ecological consequences of climate change will vary substantially among ecoregions because of regional differences in antecedent environmental conditions; the rate and magnitude of change in the primary climate change drivers, including elevated carbon dioxide (CO_2), warming and precipitation modification; and nonadditive effects among climate drivers. Elevated atmospheric CO_2 will directly stimulate plant growth and reduce negative effects of drying in a warmer climate by increasing plant water use efficiency; however, the CO_2 effect is mediated by environmental conditions, especially soil water availability. Warming and drying are anticipated to reduce soil water availability, net primary productivity, and other ecosystem processes in the southern Great Plains, the Southwest, and northern Mexico, but warmer and generally wetter conditions will likely enhance these processes in the northern Plains and southern Canada. The Northwest will warm considerably, but annual precipitation is projected to change little despite a large decrease in summer precipitation. Reduced winter snowpack and earlier snowmelt will affect hydrology and riparian systems in the Northwest. Specific consequences of climate change will be numerous and varied and include modifications to forage quantity and quality and livestock production systems, soil C content, fire regimes, livestock metabolism, and plant community composition and species distributions, including range contraction and expansion of invasive species. Recent trends and model projections indicate continued directional change and increasing variability in climate that will substantially affect the provision of ecosystem services on North American rangelands.

Polley, H. W., Isbell, F. I. and Wilsey, B. J. 2013. **Plant functional traits improve diversity-based predictions of temporal stability of grassland productivity.** Oikos 122: 1275–1282.
doi: 10.1111/j.1600-0706.2013.00338.x

Abstract. The temporal stability of plant production is greater in communities with high than low species richness, but stability also may depend on species abundances and growth-related traits. Annual precipitation varied by greater than a factor of three over 11 years in central Texas, USA leading to large variation in production. Stability was greatest in communities that were not dominated by few species and in which dominant species rooted shallowly, had dense leaves, or responded to the wettest year with a minimal increase in production. Stability may depend as much on species abundances and functional traits as on species richness alone.

Aboveground net primary productivity (ANPP) varies in response to temporal fluctuations in weather. Temporal stability of community ANPP may be increased by increasing plant species richness, but stability often varies at a given richness level implying a dependence on abundances and functional properties of member species. We measured stability in ANPP during 11 years in field plots (Texas, USA) in which we varied the richness and relative abundances of perennial grassland species at planting. We sought to identify species abundance patterns and functional traits linked to the acquisition and processing of essential resources that could be used to improve richness-based predictions of community stability. We postulated that community stability would correlate with abundance-weighted indices of traits that influence plant responses to environmental variation. Annual precipitation varied by a factor of three leading to large inter-annual variation in ANPP. Regression functions with planted and realized richness (species with > 1% of community ANPP during the final four years) explained 32% and 25% of the variance in stability, respectively. Regression models that included richness plus the fraction of community ANPP produced by the two most abundant species in combination with abundance-weighted values of either the fraction of sampled root biomass at 20–45 cm depth, leaf dry matter content (LDMC), or response to greater-than-average precipitation of plants grown in monocultures explained 58–69% (planted richness) and 58–64% (realized richness) of the variance in stability. Stability was greatest in communities that were not strongly dominated by only two species and in which plants rooted shallowly, had high values of LDMC, or responded to the wettest year with a minimal increase in ANPP. Our results indicate that the temporal stability of grassland ANPP may depend as much on species abundances and functional traits linked to plant responses to precipitation variability as on species richness alone.

Seth M. Munson. 2013. **Plant responses, climate pivot points, and trade-offs in water-limited ecosystems.** Ecosphere 4:art109. http://dx.doi.org/10.1890/ES13-00132.1

Abstract. Plant species in dryland ecosystems are limited by water availability and may be vulnerable to increases in aridity. Methods are needed to monitor and assess the rate of change in plant abundance and composition in relation to climate, understand the potential for degradation in dryland ecosystems, and forecast future changes in plant species assemblages. I employ nearly a century of vegetation monitoring data from three North American deserts to demonstrate an approach to determine plant species responses to climate and critical points over a range of climatic conditions at which plant species shift from increases to decreases in abundance (climate pivot points). I assess these metrics from a site to regional scale and highlight how these indicators of plant performance can be modified by the physical and biotic environment. For example, shrubs were more responsive to drought and high temperatures on shallow soils with limited capacity to store water and fine-textured soils with slow percolation rates, whereas perennial grasses were more responsive to precipitation in sparse shrublands than in relatively dense grasslands and shrublands, where competition for water is likely more intense. The responses and associated climate pivot points of plant species aligned with their lifespan and structural characteristics, and the relationship between responses and climate pivot points provides evidence of the trade-off between the capacity of a plant

species to increase in abundance when water is available and its drought resistance.

Fish and Wildlife

Dybala, K. E., Eadie, J. M., Gardali, T., Seavy, N. E. and Herzog, M. P. 2013. **Projecting demographic responses to climate change: adult and juvenile survival respond differently to direct and indirect effects of weather in a passerine population.** Global Change Biology 19: 2688–2697. doi: 10.1111/gcb.12228

Abstract. Few studies have quantitatively projected changes in demography in response to climate change, yet doing so can provide important insights into the processes that may lead to population declines and changes in species distributions. Using a long-term mark-recapture data set, we examined the influence of multiple direct and indirect effects of weather on adult and juvenile survival for a population of Song Sparrows (*Melospiza melodia*) in California. We found evidence for a positive, direct effect of winter temperature on adult survival, and a positive, indirect effect of prior rainy season precipitation on juvenile survival, which was consistent with an effect of precipitation on food availability during the breeding season. We used these relationships, and climate projections of significantly warmer and slightly drier winter weather by the year 2100, to project a significant increase in mean adult survival (12–17%) and a slight decrease in mean juvenile survival (4–6%) under the B1 and A2 climate change scenarios. Together with results from previous studies on seasonal fecundity and postfledging survival in this population, we integrated these results in a population model and projected increases in the population growth rate under both climate change scenarios. Our results underscore the importance of considering multiple, direct, and indirect effects of weather throughout the annual cycle, as well as differences in the responses of each life stage to climate change. Projecting demographic responses to climate change can identify not only how populations will be affected by climate change but also indicate the demographic process(es) and specific mechanisms that may be responsible. This information can, in turn, inform climate change adaptation plans, help prioritize future research, and identify where limited conservation resources will be most effectively and efficiently spent.

Llusia, D., Márquez, R., Beltrán, J. F., Benítez, M. and do Amaral, J. P. 2013. **Calling behaviour under climate change: geographical and seasonal variation of calling temperatures in ectotherms.** Global Change Biology 19: 2655–2674. doi: 10.1111/gcb.12267

Abstract. Calling behaviour is strongly temperature-dependent and critical for sexual selection and reproduction in a variety of ectothermic taxa, including anuran amphibians, which are the most globally threatened

vertebrates. However, few studies have explored how species respond to distinct thermal environments at time of displaying calling behaviour, and thus it is still unknown whether ongoing climate change might compromise the performance of calling activity in ectotherms. Here, we used new *audio-trapping* techniques (automated sound recording and detection systems) between 2006 and 2009 to examine annual calling temperatures of five temperate anurans and their patterns of geographical and seasonal variation at the thermal extremes of species ranges, providing insights into the thermal breadths of calling activity of species, and the mechanisms that enable ectotherms to adjust to changing thermal environments. All species showed wide thermal breadths during calling behaviour (above 15 °C) and increases in calling temperatures in extremely warm populations and seasons. Thereby, calling temperatures differed both geographically and seasonally, both in terrestrial and aquatic species, and were 8–22 °C below the specific upper critical thermal limits (CT_{max}) and strongly associated with the potential temperatures of each thermal environment (operative temperatures during the potential period of breeding). This suggests that calling behaviour in ectotherms may take place at population-specific thermal ranges, diverging when species are subjected to distinct thermal environments, and might imply plasticity of thermal adjustment mechanisms (seasonal and developmental acclimation) that supply species with means of coping with climate change. Furthermore, the thermal thresholds of calling at the onset of the breeding season were dissimilar between conspecific populations, suggesting that other factors besides temperature are needed to trigger the onset of reproduction. Our findings imply that global warming would not directly inhibit calling behaviour in the study species, although might affect other temperature-dependent features of their acoustic communication system.

Wade, A. A., Beechie, T. J., Fleishman, E., Mantua, N. J., Wu, H., Kimball, J. S., Stoms, D. M., and Stanford, J. A. 2013. **Steelhead vulnerability to climate change in the Pacific Northwest.** Journal of Applied Ecology 50: 1093–1104. doi: 10.1111/1365-2664.12137

Abstract. Steelhead (*Oncorhynchus mykiss*) and other Pacific salmon are threatened by unsustainable levels of harvest, genetic introgression from hatchery stocks and degradation or loss of freshwater habitat. Projected climate change is expected to further stress salmon through increases in stream temperatures and altered stream flows.

We demonstrate a spatially explicit method for assessing salmon vulnerability to projected climatic changes (scenario for the years 2030–2059), applied here to steelhead salmon across the entire Pacific Northwest (PNW). We considered steelhead exposure to increased temperatures and more extreme high and low flows during four of their primary freshwater life stages: adult migration, spawning, incubation and rearing. Steelhead sensitivity to climate change was estimated on the basis of their regulatory status and the condition of their habitat. We assessed combinations of exposure and

sensitivity to suggest actions that may be most effective for reducing steelhead vulnerability to climate change.

Our relative ranking of locations suggested that steelhead exposure to increases in temperature will be most widespread in the southern Pacific Northwest, whereas exposure to substantial flow changes will be most widespread in the interior and northern Pacific Northwest. There were few locations where we projected that steelhead had both relatively low exposure and sensitivity to climate change.

Synthesis and applications. There are few areas where habitat protection alone is likely to be sufficient to conserve steelhead under the scenario of climate change considered here. Instead, our results suggest the need for coordinated, landscape-scale actions that both increase salmon resilience and ameliorate climate change impacts, such as restoring connectivity of floodplains and high-elevation habitats.

Wainwright, Thomas C. and Laurie A. Weitkamp. 2013. **Effects of Climate Change on Oregon Coast Coho Salmon: Habitat and Life-Cycle Interactions.** Northwest Science 87(3): 219–242.

Abstract. Coho salmon (*Oncorhynchus kisutch*) populations that spawn in the coastal rivers of Oregon, U.S.A., formerly supported robust fisheries but are now listed as a "threatened species" under the U.S. Endangered Species Act. Climate change is an increasing concern in salmon conservation, and we assess the effects of climate change on sustainability of this population group. Four distinct habitats are important to different life-history stages of coho salmon: terrestrial forests, freshwater rivers and lakes, estuaries, and the ocean. Each of these habitats is affected by multiple aspects of climate change, resulting in a complex web of pathways influencing sustainability. We summarize regional climate change studies to predict future climate patterns affecting these habitats, identify the ecological pathways by which these patterns affect coho salmon, and review coho salmon ecology to assess the likely direction and magnitude of population response. Despite substantial uncertainties in specific effects and variations in effects among populations, the preponderance of negative effects throughout the life cycle indicates a significant climate-driven risk to future sustainability of these populations. We recommend that management policies for all four habitats focus on maximizing resilience to the effects of climate change as it interacts with other natural and anthropogenic changes.

Invertebrates

DeRose, R. Justin, Barbara J. Bentz, James N. Long, and John D. Shaw. 2013. **Effect of increasing temperatures on the distribution of spruce beetle in Engelmann spruce forests of the Interior West, USA.** Forest Ecology and Management 308: 198-206.

Abstract. The spruce beetle (*Dendoctronus rufipennis*) is a pervasive bark beetle indigenous to spruce (*Picea* spp.) forests of North America. In the last two decades outbreaks of spruce beetle have increased in severity and extent. Increasing temperatures have been implicated as they directly control beetle populations, potentially inciting endemic populations to build to epidemic (outbreak) proportions. However, stand structure and composition conditions will also influence beetle populations. We tested the effect of temperature variables (minimum cool season temperature and maximum warm season temperature), and habitat controls (structure and composition) on the prediction of spruce beetle presence/absence for 4198 Engelmann spruce (*Picea engelmannii* Parry ex. Engelm.) plots in the Interior West, USA. Predictions were applied to three global climate models (GCMs) for three time periods. While both temperature variables were important, results suggested habitat variables (spruce basal area and spruce composition) were more influential for the prediction of current beetle presence. Future beetle prevalence varied from 6.1% to 24.2% across GCMs and time periods. While both temperature variables increased over time, in some cases the increases were not proportional, which led to differential predictions of beetle population prevalence in space and time among GCMs. Habitat variables that characterized current spruce beetle susceptibility changed as future temperatures increased. Application of results to forest management will include adjusting monitoring programs to reflect the potential increased overall prevalence of the beetle, and modifying the characterization of high hazard spruce stands to reflect increasing beetle presence in stands with lower basal area and spruce composition than currently observed.

Soils and Hydrology

Furniss, Michael J.; Roby, Ken B.; Cenderelli, Dan; Chatel, John; Clifton, Caty F.; Clingenpeel, Alan; Hays, Polly E.; Higgins, Dale; Hodges, Ken; Howe, Carol; Jungst, Laura; Louie, Joan; Mai, Christine; Martinez, Ralph; Overton, Kerry; Staab, Brian P.; Steinke, Rory; and Weinhold, Mark. 2013. **Assessing the vulnerability of watersheds to climate change: results of national forest watershed vulnerability pilot assessments.** Gen. Tech. Rep. PNW-GTR-884. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 p. plus appendix. Available at http://treesearch.fs.fed.us/pubs/43898

Abstract. Existing models and predictions project serious changes to worldwide hydrologic processes as a result of global climate change. Projections indicate that significant change may threaten National Forest System watersheds that are an important source of water used to support people, economies, and ecosystems.

Wildland managers are expected to anticipate and respond to these threats, adjusting management priorities and actions. Because watersheds differ greatly in: (1) the values they support, (2) their exposure to climatic changes, and (3) their sensitivity to climatic changes, understanding these differences will help inform the setting of priorities and selection of management approaches. Drawing distinctions in climate change vulnerability among watersheds on a national forest or grassland allows more efficient and effective allocation of resources and better land and watershed stewardship.

Eleven national forests from throughout the United States, representing each of the nine Forest Service regions, conducted assessments of potential hydrologic change resulting from ongoing and expected climate warming. A pilot assessment approach was developed and implemented. Each national forest identified water resources important in that area, assessed climate change exposure and watershed sensitivity, and evaluated the relative vulnerabilities of watersheds to climate change. The assessments provided management recommendations to anticipate and respond to projected climate-hydrologic changes.

Completed assessments differed in level of detail, but all assessments identified priority areas and management actions to maintain or improve watershed resilience in response to a changing climate. The pilot efforts also identified key principles important to conducting future vulnerability assessments.

Kuiper, I., de Deyn, G. B., Thakur, M. P. and van Groenigen, J. W. 2013. **Soil invertebrate fauna affect N_2O emissions from soil.** Global Change Biology 19: 2814–2825. doi: 10.1111/gcb.12232

Abstract. Nitrous oxide (N_2O) emissions from soils contribute significantly to global warming. Mitigation of N_2O emissions is severely hampered by a lack of understanding of its main controls. Fluxes can only partly be predicted from soil abiotic factors and microbial analyses – a possible role for soil fauna has until now largely been overlooked. We studied the effect of six groups of soil invertebrate fauna and tested the hypothesis that all of them increase N_2O emissions, although to different extents. We conducted three microcosm experiments with sandy soil and hay residue. Faunal groups included in our experiments were as follows: fungal-feeding nematodes, mites, springtails, potworms, earthworms and isopods. In experiment I, involving all six faunal groups, N_2O emissions declined with earthworms and potworms from 78.4 (control) to 37.0 (earthworms) or 53.5 (potworms) mg N_2O-N m^{-2}. In experiment II, with a higher soil-to-hay ratio and mites, springtails and potworms as faunal treatments, N_2O emissions increased with potworms from 51.9 (control) to 123.5 mg N_2O-N m^{-2}. Experiment III studied the effect of potworm density; we found that higher densities of potworms accelerated the peak of the N_2O emissions by 5 days ($P < 0.001$), but the cumulative N_2O emissions remained unaffected. We propose that increased soil aeration by the soil fauna reduced N_2O emissions in experiment I, whereas in experiment II N_2O emissions were driven by increased nitrogen and carbon availability. In experiment III, higher densities of potworms accelerated nitrogen and carbon availability and N_2O emissions, but did not increase them. Overall, our data show that soil fauna can suppress, increase, delay or accelerate N_2O emissions from soil and should therefore be an integral part of future N_2O studies.

Wu, Peili, Nikolaos Christidis and Peter Stott. 2013. **Anthropogenic impact on Earth's hydrological cycle.** Nature Climate Change 3: 807–810. doi:10.1038/nclimate1932

Abstract. The global hydrological cycle is a key component of Earth's climate system. A significant amount of the energy the Earth receives from the Sun is redistributed around the world by the hydrological cycle in the form of latent heat flux. Changes in the hydrological cycle have a direct impact on droughts, floods, water resources and ecosystem services. Observed land precipitation and global river discharges do not show an increasing trend as might be expected in a warming world. Here we show that this apparent discrepancy can be resolved when the effects of tropospheric aerosols are considered. Analysing state-of-the-art climate model simulations, we find for the first time that there was a detectable weakening of the hydrological cycle between the 1950s and the 1980s, attributable to increased anthropogenic aerosols, after which the hydrological cycle recovered as a result of increasing greenhouse gas concentrations. The net result of these two counter-acting effects is an insignificant trend in the

global hydrological cycle, but the individual influence of each is substantial. Reductions in air pollution have already shown an intensification in the past two decades and a further rapid increase in precipitation could be expected if the current trend continues.

Zeglin, L. H., P. J. Bottomley, A. Jumpponen, C. W. Rice, M. Arango, A. Lindsley, A. McGowan, P. Mfombep, and D. D. Myrold. 2013. **Altered precipitation regime affects the function and composition of soil microbial communities on multiple time scales.** Ecology 94:2334–2345. http://dx.doi.org/10.1890/12-2018.1

Abstract. Climate change models predict that future precipitation patterns will entail lower-frequency but larger rainfall events, increasing the duration of dry soil conditions. Resulting shifts in microbial C cycling activity could affect soil C storage. Further, microbial response to rainfall events may be constrained by the physiological or nutrient limitation stress of extended drought periods; thus seasonal or multiannual precipitation regimes may influence microbial activity following soil wet-up. We quantified rainfall-driven dynamics of microbial processes that affect soil C loss and retention, and microbial community composition, in soils from a long-term (14-year) field experiment contrasting "Ambient" and "Altered" (extended intervals between rainfalls) precipitation regimes. We collected soil before, the day following, and five days following 2.5-cm rainfall events during both moist and dry periods (June and September 2011; soil water potential = −0.01 and −0.83 MPa, respectively), and measured microbial respiration, microbial biomass, organic matter decomposition potential (extracellular enzyme activities), and microbial community composition (phospholipid fatty acids). The equivalent rainfall events caused equivalent microbial respiration responses in both treatments. In contrast, microbial biomass was higher and increased after rainfall in the Altered treatment soils only, thus microbial C use efficiency (CUE) was higher in Altered than Ambient treatments (0.70 ± 0.03 > 0.46 ± 0.10). CUE was also higher in dry (September) soils. C-acquiring enzyme activities (β-glucosidase, cellobiohydrolase, and phenol oxidase) increased after rainfall in moist (June), but not dry (September) soils. Both microbial biomass C:N ratios and fungal : bacterial ratios were higher at lower soil water contents, suggesting a functional and/or population-level shift in the microbiota at low soil water contents, and microbial community composition also differed following wet-up and between seasons and treatments. Overall, microbial activity may directly (C respiration) and indirectly (enzyme potential) reduce soil organic matter pools less in drier soils, and soil C sequestration potential (CUE) may be higher in soils with a history of extended dry periods between rainfall events. The implications include that soil C loss may be reduced or compensated for via different mechanisms at varying time scales, and that microbial taxa with better stress tolerance or growth efficiency may be associated with these functional shifts.

Fire

Abatzoglou, John T. and Crystal A. Kolden. 2013**. Relationships between climate and macroscale area burned in the western United States.** International Journal of Wildland Fire 22(7) 1003-1020 http://dx.doi.org/10.1071/WF13019

Abstract. Increased wildfire activity (e.g. number of starts, area burned, fire behaviour) across the western United States in recent decades has heightened interest in resolving climate–fire relationships. Macroscale climate–fire relationships were examined in forested and non-forested lands for eight Geographic Area Coordination Centers in the western United States, using area burned derived from the Monitoring Trends in Burn Severity dataset (1984–2010). Fire-specific biophysical variables including fire danger and water balance metrics were considered in addition to standard climate variables of monthly temperature, precipitation and drought indices to explicitly determine their optimal capacity to explain interannual variability in area burned. Biophysical variables tied to the depletion of fuel and soil moisture and prolonged periods of elevated fire-danger had stronger correlations to area burned than standard variables antecedent to or during the fire season, particularly in forested systems. Antecedent climate–fire relationships exhibited inter-region commonality with area burned in forested lands correlated with winter snow water equivalent and emergent drought in late spring. Area burned in non-forested lands correlated with moisture availability in the growing season preceding the fire year. Despite differences in the role of antecedent climate in preconditioning fuels, synchronous regional fire activity in forested and non-forested lands suggests that atmospheric conditions during the fire season unify fire activity and can compound or supersede antecedent climatic stressors. Collectively, climate–fire relationships viewed through the lens of biophysical variables provide a more direct link to fuel flammability and wildfire activity than standard climate variables, thereby narrowing the gap in incorporating top-down climatic factors between empirical and process-based fire models.

Luo, Lifeng, Ying Tang, Shiyuan Zhong, Xindi Bian, and Warren E. Heilman. 2013. **Will Future Climate Favor More Erratic Wildfires in the Western United States?** Journal of Applied Meteorology and Climatology 52: 2410–2417. doi: http://dx.doi.org/10.1175/JAMC-D-12-0317.1

Abstract. Wildfires that occurred over the western United States during August 2012 were fewer in number but larger in size when compared with all other Augusts in the twenty-first century. This unique characteristic, along with the tremendous property damage and potential loss of life that occur with large wildfires with erratic behavior, raised the question of whether future climate will favor rapid wildfire growth so that similar wildfire activity may become more frequent as climate changes. This study addresses this question by examining differences in the climatological distribution of the

Haines index (HI) between the current and projected future climate over the western United States. The HI, ranging from 2 to 6, was designed to characterize dry, unstable air in the lower atmosphere that may contribute to erratic or extreme fire behavior. A shift in HI distribution from low values (2 and 3) to higher values (5 and 6) would indicate an increased risk for rapid wildfire growth and spread. Distributions of Haines index are calculated from simulations of current (1971–2000) and future (2041–70) climate using multiple regional climate models in the North American Regional Climate Change Assessment Program. Despite some differences among the projections, the simulations indicate that there may be not only more days but also more consecutive days with HI ≥ 5 during August in the future. This result suggests that future atmospheric environments will be more conducive to erratic wildfires in the mountainous regions of the western United States.

Socio-Economics

Dittmer, Kyle. 2013. **Changing streamflow on Columbia basin tribal lands—climate change and salmon.** Climatic Change 120(3): 627-641.

Abstract. Over the last 100 years, linear trends of tributary streamflow have changed on Columbia River Basin tribal reservations and historical lands ceded by tribes in treaties with the United States. Analysis of independent flow measures (Seasonal Flow Fraction, Center Timing, Spring Flow Onset, High Flow, Low Flow) using the Student *t* test and Mann-Kendall trend test suggests evidence for climate change trends for many of the 32 study basins. The trends exist despite interannual climate variability driven by the El Niño–Southern Oscillation and Pacific Decadal Oscillation. The average April—July flow volume declined by 16 %. The median runoff volume date has moved earlier by 5.8 days. The Spring Flow Onset date has shifted earlier by 5.7 days. The trend of the flow standard deviation (i.e., weather variability) increased 3 % to 11 %. The 100-year November floods increased 49 %. The mid-Columbia 7Q10 low flows have decreased by 5 % to 38 %. Continuation of these climatic and hydrological trends may seriously challenge the future of salmon, their critical habitats, and the tribal peoples who depend upon these resources for their traditional livelihood, subsistence, and ceremonial purposes.

Lynn, Kathy, John Daigle, Jennie Hoffman, Frank Lake, Natalie Michelle, Darren Ranco, Carson Viles, Garrit Voggesser, and Paul Williams. 2013. **The impacts of climate change on tribal traditional foods.** Climatic Change 120(3): 545-556.

Abstract. American Indian and Alaska Native tribes are uniquely affected by climate change. Indigenous peoples have depended on a wide variety of native fungi, plant and animal species for food, medicine, ceremonies, community and economic health for countless generations. Climate change stands to impact the species and ecosystems that constitute tribal traditional foods that are vital to tribal culture, economy and traditional ways of life. This paper examines the impacts of climate change on tribal traditional foods by providing cultural context for the importance of traditional foods to tribal culture, recognizing that tribal access to traditional food resources is strongly influenced by the legal and regulatory relationship with the federal government, and examining the multi-faceted relationship that tribes have with places, ecological processes and species. Tribal participation in local, regional and national climate change adaption strategies, with a focus on food-based resources, can inform and strengthen the ability of both tribes and other governmental resource managers to address and adapt to climate change impacts.

Voggesser,Garrit, Kathy Lynn, John Daigle, Frank K. Lake, and Darren Ranco. 2013. **Cultural impacts to tribes from climate change influences on forests.** Climatic Change 120(3): 615-626.

Abstract. Climate change related impacts, such as increased frequency and intensity of wildfires, higher temperatures, extreme changes to ecosystem processes, forest conversion and habitat degradation are threatening tribal access to valued resources. Climate change is and will affect the quantity and quality of resources tribes depend upon to perpetuate their cultures and livelihoods. Climate impacts on forests are expected to directly affect culturally important fungi, plant and animal species, in turn affecting tribal sovereignty, culture, and economy. This article examines the climate impacts on forests and the resulting effects on tribal cultures and resources. To understand potential adaptive strategies to climate change, the article also explores traditional ecological knowledge and historical tribal adaptive approaches in resource management, and contemporary examples of research and tribal practices related to forestry, invasive species, traditional use of fire and tribal-federal coordination on resource management projects. The article concludes by summarizing tribal adaptive strategies to climate change and considerations for strengthening the federal-tribal relationship to address climate change impacts to forests and tribal valued resources.

Vinyeta, Kirsten and Lynn, Kathy. 2013. **Exploring the role of traditional ecological knowledge in climate change initiatives.** Gen. Tech. Rep. PNW-GTR-879. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 37 p. Available at http://treesearch.fs.fed.us/pubs/43431

Abstract. Indigenous populations are projected to face disproportionate impacts as a result of climate change in comparison to nonindigenous populations. For this reason, many American Indian and Alaska Native tribes are identifying and implementing culturally appropriate strategies to assess climate impacts and adapt to projected changes. Traditional ecological

knowledge (TEK), as the indigenous knowledge system is called, has the potential to play a central role in both indigenous and nonindigenous climate change initiatives. The detection of environmental changes, the development of strategies to adapt to these changes, and the implementation of sustainable land-management principles are all important climate action items that can be informed by TEK. Although there is a significant body of literature on traditional knowledge, this synthesis examines literature that specifically explores the relationship between TEK and climate change. The synthesis describes the potential role of TEK in climate change assessment and adaptation efforts. It also identifies some of the challenges and benefits associated with merging TEK with Western science, and reviews the way in which federal policies and administrative practices facilitate or challenge the incorporation of TEK in climate change initiatives. The synthesis highlights examples of how tribes and others are including TEK into climate research, education, and resource planning and explores strategies to incorporate TEK into climate change policy, assessments, and adaptation efforts at national, regional, and local levels.

Adaptation

Akira S. Mori, Thomas A. Spies, Karen Sudmeier-Rieux, and Angela Andrade. 2013. **Reframing ecosystem management in the era of climate change: Issues and knowledge from forests.** Biological Conservation 165: 115-127.

Abstract. Climate change is one of the significant concerns in land and resource management, creating an urgent need to build social–ecological capacity to address widespread and uncertain environmental changes. Given the diversity and complexity of ecological responses to climate change "ecosystem management" approaches are needed to provide solutions for meeting both ecological and human needs, while reducing anthropogenic warming and climate-related impacts on society. For instance, ecosystem management can contribute to a reduction in the greenhouse gas emissions through improved land-use and reduced deforestation at a regional scale. Further, conserving and restoring naturally-functioning ecosystems, which is often one of the goals of ecosystem management can significantly contribute to buffering ecological responses to climate extremes such as droughts and wildfires. Moreover, ecosystem management helps build capacity for learning and adaptation at multiple scales. As a result, societies will be better prepared to respond to surprises and uncertainties associated with climate change. In this regard, it is imperative to reframe climate change issues based on the ecosystem approach. Although climate change and ecosystem management plans have largely developed independently, it is now essential for all stakeholders to work together to achieve multiple goals. The ecosystem-based approaches can enable flexible and effective responses to the uncertainties associated with climate change. Reframing ecosystem management helps to face an urgent need for reconsideration and improvement of social–ecological resilience in order to mitigate and adapt to the changing climate.

Benito-Garzón, M., Ha-Duong, M., Frascaria-Lacoste, N. and Fernández-Manjarrés, J. 2013. **Habitat Restoration and Climate Change: Dealing with Climate Variability, Incomplete Data, and Management Decisions with Tree Translocations.** Restoration Ecology 21: 530–536. doi: 10.1111/rec.12032

Abstract. Restoration programs need to increasingly address both the restitution of biodiversity and ecosystem services and the preparation of habitats for future climate change. One option to adapt habitats to climate change in the temperate zone is the translocation of southern populations to compensate for climate change effects—an option known as assisted migration (AM). Although AM is widely criticized for endangered species, forest managers are more confident that tree populations can be translocated with success because of previous experiences within native ranges. Here, we contend that translocations of tree populations are also subject to uncertainties, and we extract lessons for future programs of AM within species ranges from a well-documented failed case of population translocation of *Pinus pinaster* Ait. in Europe. The failure of these translocations originated from the unawareness of several unpredictable ecological and social events: cryptic maladaptation of the introduced populations, underestimation of climate variability differences between the source and target sites, and complexity in the management schemes, postponing decisions that could have been undertaken earlier. Under the no-analog conditions that are expected with climate change, management decisions need to be made with incomplete data, implying that a certain degree of maladaptation should always be expected when restoring plant populations from local or external seed sources.

Buma, B. and C.A. Wessman. 2013. **Forest resilience, climate change, and opportunities for adaptation: A specific case of a general problem.** Forest Ecology and Management 306: 216-225.

Abstract. Ecosystems and ecosystem services are subjected to both typical disturbances (e.g., fire) and shifting climatic baselines resulting from anthropogenic drivers. Recovery from these perturbations is of prime interest to researchers and land managers. We explore how differing regeneration of the coniferous forest to specific disturbances and a shifting climate are mediated through managerial responses, in terms of both species composition and an important ecosystem service, carbon sequestration in the southern Rocky Mountains, Colorado, USA. 112 sites across a variety of disturbance histories were surveyed for post-fire regeneration; carbon stock growth was then simulated in the US Forest Service Forest Vegetation Simulator under a variety of climate change scenarios for 100 years.

Simultaneously, we simulated three managerial responses to the disturbance: no action, planting of local species (resilience-oriented management), and planting of the most climatically suitable species (adaptation-oriented management). These managerial responses simulate varying levels of intervention which attempt to maintain forest properties and associated carbon stocks. Carbon stocks, initially, were more resilient than the coniferous forest system; areas with little coniferous regeneration recovered carbon at a similar pace due to an influx of deciduous seedlings. However, future climate exerts a strong influence on carbon stocks. Both the no-action scenario and the resilience-oriented management scenario transitioned to non-forest by the end of the simulation period, due to climatic changes. Active, adaptation-oriented management, which included establishment of non-local species, maintained forest structure and carbon stocks under most future climate projections, albeit at lower densities. So while this preserves the presence of a forest, it does not preserve the presence of a specific forest. However, for ecosystem services associated with the mere existence of forest cover (e.g., carbon stocks and general forest habitat), this may be sufficient. In a sense, disturbances are opportunities for more climatically-adapted species/communities to establish, although the complexities of assisted migration and novel ecosystems remain.

Gustafson, Eric J. 2013. **When relationships estimated in the past cannot be used to predict the future: using mechanistic models to predict landscape ecological dynamics in a changing world.** Landscape Ecology 28(8): 1429-1437.

Abstract. Researchers and natural resource managers need predictions of how multiple global changes (e.g., climate change, rising levels of air pollutants, exotic invasions) will affect landscape composition and ecosystem function. Ecological predictive models used for this purpose are constructed using either a mechanistic (process-based) or a phenomenological (empirical) approach, or combination. Given the accelerating pace of global changes, it is becoming increasingly difficult to trust future projections made by phenomenological models estimated under past conditions. Using forest landscape models as an example, I review current modeling approaches and propose principles for developing the next generation of landscape models. First, modelers should increase the use of mechanistic components based on appropriately scaled “first principles” even though such an approach is not without cost and limitations. Second, the interaction of processes within a model should be designed to minimize a priori constraints on process interactions and mimic how interactions play out in real life. Third, when a model is expected to make accurate projections of future system states it must include all of the major ecological processes that structure the system. A completely mechanistic approach to the molecular level is not tractable or desirable at landscape scales. I submit that the best solution is to blend mechanistic and phenomenological approaches in a way that maximizes the use of mechanisms where novel driver conditions are expected while keeping

the model tractable. There may be other ways. I challenge landscape ecosystem modelers to seek new ways to make their models more robust to the multiple global changes occurring today.

Joyce, Linda A., David D. Briske, Joel R. Brown, H. Wayne Polley, Bruce A. McCarl, and Derek W. Bailey. 2013. **Climate Change and North American Rangelands: Assessment of Mitigation and Adaptation Strategies.** Rangeland Ecology and Management 66(5): 512–528.

Abstract. Recent climatic trends and climate model projections indicate that climate change will modify rangeland ecosystem functions and the services and livelihoods that they provision. Recent history has demonstrated that climatic variability has a strong influence on both ecological and social components of rangeland systems and that these systems possess substantial capacity to adapt to climatic variability. Specific objectives of this synthesis are to: 1) evaluate options to mitigate greenhouse gas emissions and future climate change; 2) survey actions that individuals, enterprises, and social organizations can use to adapt to climate change; and 3) assess options for system transformation when adaptation is no longer sufficient to contend with climate change. Mitigation for carbon sequestration does not appear economically viable, given the small and highly variable carbon dioxide fluxes of rangeland ecosystems and the high transaction costs that would be incurred. In contrast, adaptation strategies are numerous and provide a means to manage risks associated with climate change. Adaptation strategies are diverse, including altered risk perception by individuals, greater flexibility of production enterprises, and modifications to social organizations that emphasize climatic variability, rather than consistency. Many adaptations represent “no regrets” actions because their implementation can be justified without emphasis on pending climate change. Adaptations specific to livestock production systems can include flexible herd management, alternative livestock breeds or species, innovative pest management, modified enterprise structures, and geographic relocation. Social-ecological systems in which adaptation is insufficient to counter the adverse consequences of climate change might undergo transformative change to produce alternative ecosystem services, production enterprises, and livelihoods. The rangeland profession is in a pivotal position to provide leadership on this global challenge because it represents the intersection of management and scientific knowledge, includes diverse stakeholders who derive their livelihoods from rangelands, and interacts with organizations responsible for rangeland stewardship.

Stein, Bruce A., Amanda Staudt, Molly S Cross, Natalie S Dubois, Carolyn Enquist, Roger Griffis, Lara J Hansen, Jessica J Hellmann, Joshua J Lawler, Erik J Nelson, and Amber Pairis. 2013. **Preparing for and managing change: climate adaptation for biodiversity and ecosystems.** Frontiers in Ecology and the Environment 11: 502–510. http://dx.doi.org/10.1890/120277

Abstract. The emerging field of climate-change adaptation has experienced a dramatic increase in attention as the impacts of climate change on biodiversity and ecosystems have become more evident. Preparing for and addressing these changes are now prominent themes in conservation and natural resource policy and practice. Adaptation increasingly is viewed as a way of managing change, rather than just maintaining existing conditions. There is also increasing recognition of the need not only to adjust management strategies in light of climate shifts, but to reassess and, as needed, modify underlying conservation goals. Major advances in the development of climate-adaptation principles, strategies, and planning processes have occurred over the past few years, although implementation of adaptation plans continues to lag. With ecosystems expected to undergo continuing climate-mediated changes for years to come, adaptation can best be thought of as an ongoing process, rather than as a fixed endpoint.

Sletvold, N., Dahlgren, J. P., Øien, D.-I., Moen, A. and Ehrlén, J. 2013. **Climate warming alters effects of management on population viability of threatened species: results from a 30-year experimental study on a rare orchid.** Global Change Biology 19: 2729–2738. doi: 10.1111/gcb.12167

Abstract. Climate change is expected to influence the viability of populations both directly and indirectly, via species interactions. The effects of large-scale climate change are also likely to interact with local habitat conditions. Management actions designed to preserve threatened species therefore need to adapt both to the prevailing climate and local conditions. Yet, few studies have separated the direct and indirect effects of climatic variables on the viability of local populations and discussed the implications for optimal management. We used 30 years of demographic data to estimate the simultaneous effects of management practice and among-year variation in four climatic variables on individual survival, growth and fecundity in one coastal and one inland population of the perennial orchid *Dactylorhiza lapponica* in Norway. Current management, mowing, is expected to reduce competitive interactions. Statistical models of how climate and management practice influenced vital rates were incorporated into matrix population models to quantify effects on population growth rate. Effects of climate differed between mown and control plots in both populations. In particular, population growth rate increased more strongly with summer temperature in mown plots than in control plots. Population growth rate declined with spring temperature in the inland population, and with precipitation in the coastal population, and the decline was stronger in control plots in both populations.

These results illustrate that both direct and indirect effects of climate change are important for population viability and that net effects depend both on local abiotic conditions and on biotic conditions in terms of management practice and intensity of competition. The results also show that effects of management practices influencing competitive interactions can strongly depend on climatic factors. We conclude that interactions between climate and management should be considered to reliably predict future population viability and optimize conservation actions.

Mitigation

DeLonge, Marcia S., Rebecca Ryals, and Whendee L. Silver. 2013. **A Lifecycle Model to Evaluate Carbon Sequestration Potential and Greenhouse Gas Dynamics of Managed Grasslands.** Ecosystems 16(6): 962-979.

Abstract. Soil amendments can increase net primary productivity (NPP) and soil carbon (C) sequestration in grasslands, but the net greenhouse gas fluxes of amendments such as manure, compost, and inorganic fertilizers remain unclear. To evaluate opportunities for climate change mitigation through soil amendment applications, we designed a field-scale model that quantifies greenhouse gas emissions (CO_2, CH_4, and N_2O) from the production, application, and ecosystem response of soil amendments. Using this model, we developed a set of case studies for grazed annual grasslands in California. Sensitivity tests were performed to explore the impacts of model variables and management options. We conducted Monte Carlo simulations to provide estimates of the potential error associated with variables where literature data were sparse or spanned wide ranges. In the base case scenario, application of manure slurries led to net emissions of 14 Mg CO_2e ha^{-1} over a 3-year period. Inorganic N fertilizer resulted in lower greenhouse gas emissions than the manure (3 Mg CO_2e ha^{-1}), assuming equal rates of N addition and NPP response. In contrast, composted manure and plant waste led to large offsets that exceeded emissions, saving 23 Mg CO_2e ha^{-1} over 3 years. The diversion of both feedstock materials from traditional high-emission waste management practices was the largest source of the offsets; secondary benefits were also achieved, including increased plant productivity, soil C sequestration, and reduced need for commercial feeds. The greenhouse gas saving rates suggest that compost amendments could result in significant offsets to greenhouse gas emissions, amounting to over 28 MMg CO_2e when scaled to 5% of California rangelands. We found that the model was highly sensitive to manure and landfill management factors and less dependent on C sequestration, NPP, and soil greenhouse gas effluxes. The Monte Carlo analyses indicated that compost application to grasslands is likely to lead to net greenhouse gas offsets across a broad range of potential environmental and management conditions. We conclude that applications of composted organic matter to grasslands can contribute to

climate change mitigation while sustaining productive lands and reducing waste loads.