for low and high trophic level species. We suggest that this may be particularly the case in systems where the bulk of primary production or habitat structure is provided by only a few dominant plant species. In such systems, climatically induced changes in plant-soil interactions may produce cascading effects at higher trophic levels, resulting in changed whole-ecosystem responses to restoration efforts. It is possible that other ecosystems may face similar challenges and we propose that other restoration ecologists consider this issue.

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Atlases of Tree and Bird Species Habitats for Current and Future Climates

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As human-induced climate change is increasingly recognized as a major player in the field of ecology, numerous studies have documented its impact on species, communities, and ecosystems. However, very few studies have systematically explored the impacts on a whole suite of species over a wide geographic region. In an effort to do so, we have developed two atlases (www/nrs.fs.fed.us/atlas) related to 134 tree and 147 bird species of the eastern United States (nearly all species in the region with sampling and observations adequate for statistical modeling). The atlases provide distributional, ecological, and biological information on these species, as well as modelled results on current and potential future habitats. Our purpose, in addition to providing extensive species-specific and combined-species information, is to help managers and restoration ecologists get a clearer picture of how possible habitat changes may impact their county, state, national forest, or other areas of interest.

To estimate abundance for each species, we used the U.S. Forest Service's Forest Inventory Analysis (FIA) data and derived tree importance values (IVs) from the basal area and number of stems in the understory and overstory. Data from the Breeding Bird Survey (BBS) were used to derive bird incidence (proportion of years that a species was observed on a particular route across ten years of sampling). The FIA and BBS data allow us to model relative abundances, unlike the limited presence/absence information obtainable from traditional sources like herbaria or county-based records. We used a statistical data mining approach (regression trees, bagging, and RandomForest) to model the effects of climate, soil, elevation, and landscape predictors on the abundances of the tree species and to predict changes in the distribution of potential habitats for future climates (Prasad et al. 2006, Iverson et al. 2008). A similar approach was used for the bird species, except that, in addition to climate, we used the current and modeled tree species abundances to predict potential changes in bird habitat (Rodenhouse et al. 2008).

Because our data were nonlinear and nonparametric with numerous hidden interactions, they violated most statistical assumptions, and traditional parametric statistical approaches would have poorly captured these complex patterns. Newer machine-learning, data-driven approaches using decision-tree ensembles have a proven record of robust prediction, and also provide valuable insights into the important predictors influencing species distribution.

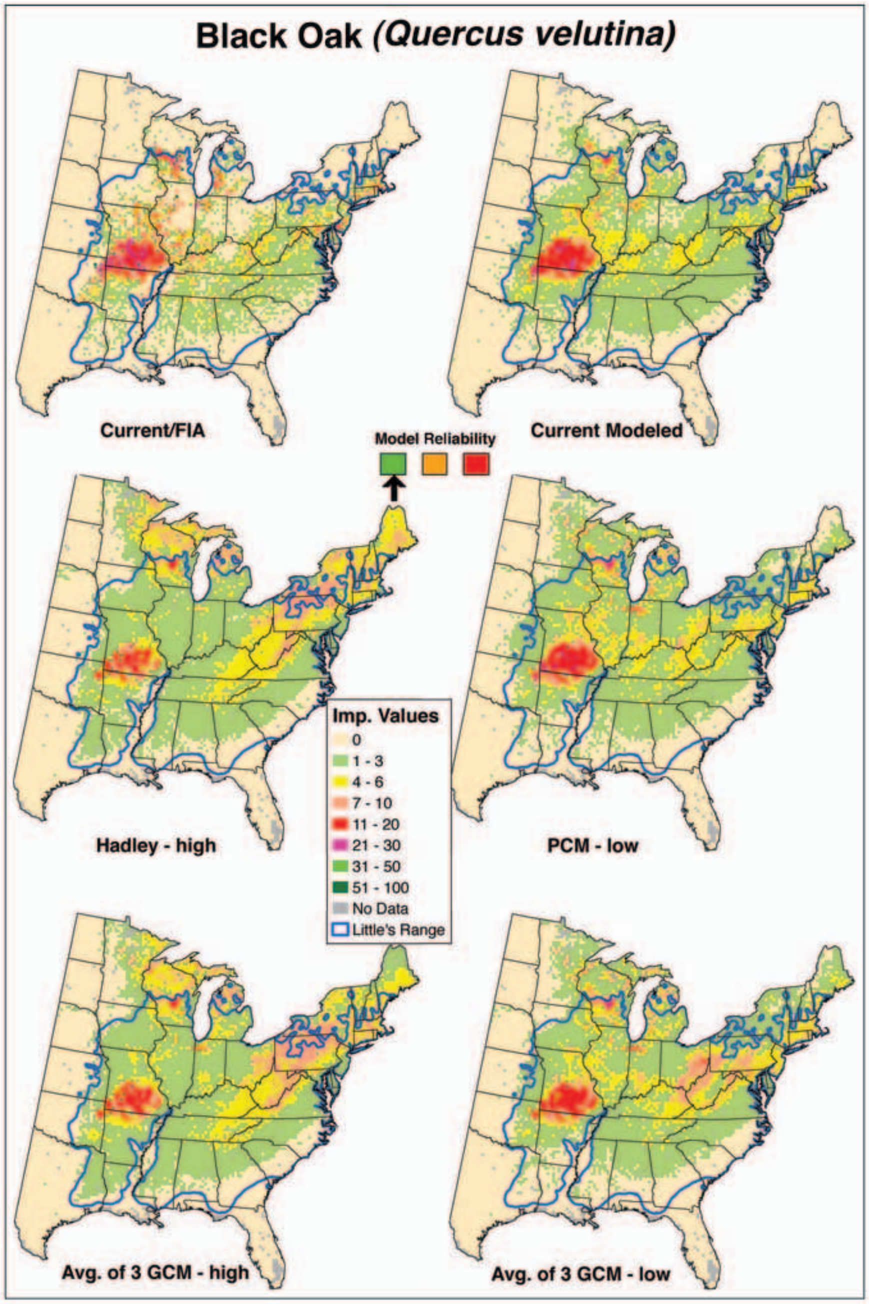

Figure 1. Importance values for black oak from current Forest Inventory Analysis (FIA) data and modeled current (RF) and future climates. Hadley High is the harshest of the future scenarios and PCM Low the mildest (middle row). The bottom row represents the averages of PCM, HadleyCM3 and GFDL general climate models (GCM) for high and low carbon emission scenarios. Green (left square) represents the most accurate model reliability.

It should, however, be noted that because some species are easier to model than others (for example, those with highly restricted ranges vs. those with highly general ranges), there are differences in the reliability of the predictions among species. We therefore statistically assessed the reliability of predicted IV for each species and classified it as high, medium, or low to capture the differences in the quality of the individual species model outputs.

Three Global Circulation Models (GCMs) (the Parallel Climate Model [PCM], the Hadley CM3 model, and the Geophysical Fluid Dynamics Laboratory [GFDL] model), were used for two future climate scenarios driven by carbon emissions described by the Intergovernmental Panel on Climate Change (IPCC): *high* (current carbon emissions trajectory—A1fi) and *low* (reasonable conservation of energy implemented—B1). These climate models represent the current range of climate predictions and incorporate both the mild (PCM) and harsh (Hadley) scenarios and explore how the A1fi and B1 emission scenarios can be crucial in affecting future species habitat distribution. Modeling this mix therefore represents a sensitivity analysis of possible future climate scenarios. We emphasize that we model *potential future suitable habitats* and not actual future distributions, as our model does not directly account for several biotic and abiotic factors that could affect the final outcome.

The main page of the tree atlas (www.nrs.fs.fed.us/atlas/tree/tree_atlas.html) presents the user with a sortable table of 134 species, which provides an entry point to further explore each species. For example, if one is interested in

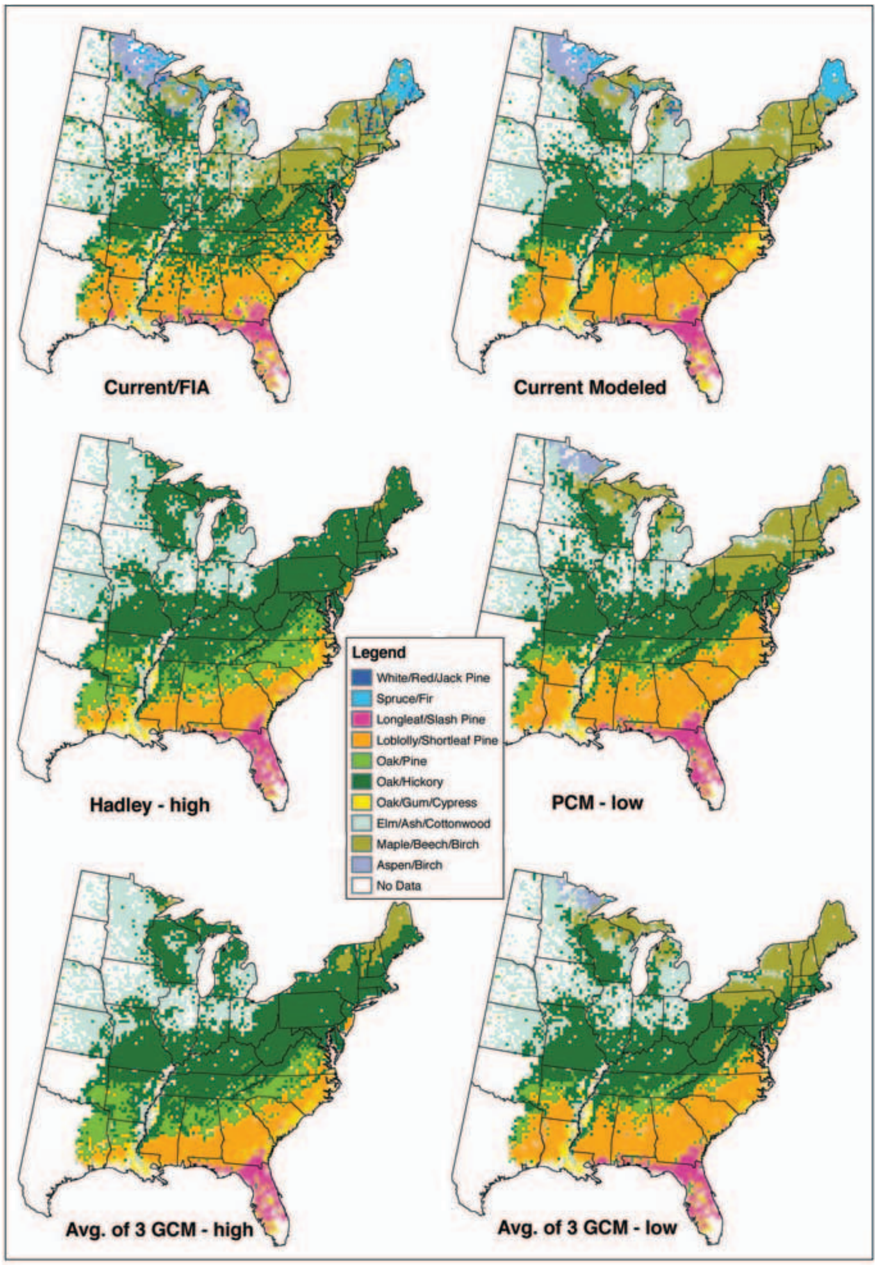

Figure 2. Maps of current and potential future suitable habitat for the USDA Forest Service forest types for FIA and modeled current (top row) and future climates. Hadley High is the harshest of the future scenarios and PCM Low the mildest (middle row). The bottom row represents the averages of PCM, HadleyCM3 and GFDL general climate models (GCM) for high and low carbon emission scenarios.

black oak (*Quercus velutina*), a quick way to review modeled current and future habitats is to click the link for "Summary Change Maps" (Figure 1), which show the current distribution of black oak under current FIA and several modeled outcomes. Here, "RF-Current" is the predicted current distribution based on our model; "Hadley Hi" is the harshest of the GCM scenarios; "PCM Lo" is the mildest; and "GCM3AvgHi" and "GCM3AvgLo" are the average of the three GCMs under high and low emission scenarios. Black oak's potential habitat moves north and northeast by the end of the century, especially under the higher emission scenario. Notice also that black oak has high model reliability, meaning that we have greater confidence in the modeled results.

In addition to the species-specific information, the main atlas page also provides links that summarize all species (www.nrs.fs.fed.us/atlas/tree/trees_alltogether.html) and the predictors used in the model (www.nrs.fs.fed.us/atlas/tree/map_predictors.html). These allow users to make comparisons among all 134 species. For example, if restoration ecologists were concerned about what species would be at risk of losing habitat, they would explore the "Potential Species Winners and Losers by State" link in the "Modeled-Future Habitats" tab. This information can be sorted by state, mean IV change, and model reliability.

Another product that could be useful to forest managers is the potential changes to forest types (www.nrs.fs.fed.us/atlas/tree/fut_fortypes.html) (Figure 2). Here we combine the IVs and classify them according to U.S. Forest Service forest types, then determine potential changes (www.nrs.fs.fed.us/atlas/tree/ft_summary.html). Such model combinations suggest a retreat of the spruce-fir zone and an advance of the southern oaks and pines, providing management insights for forest managers grappling with such issues.

The bird atlas for 147 individual bird species is similar to the tree atlas, with combined species outputs and summaries of predictors (www.nrs.fs.fed.us/atlas/bird/bird_atlas.html). Though it is not as exhaustive as the tree atlas, we do provide a great deal of information about each species in conjunction with environmental and tree species data, as well as modeled results of potential changes in bird incidence under the same scenarios of climate change. The unique aspect here is that the bird models depend on the modeled outputs of the tree species in addition to climate.

We have provided a glimpse of our tree and bird atlases, but have by no means been exhaustive in our coverage. There are many maps, tables, statistics, and other features that we have not attempted to explain here, and we invite readers to explore the depth of the web site, and provide feedback. Context-sensitive help can assist with interpreting the outputs (click on the "?"). We are also actively pursuing enhancements to this work, which will eventually be reflected in the web sites, including a cell-based model to assess probability of colonization within 100 years and ways to incorporate biological, disturbance, and modeling factors not currently well represented in our statistical models.

The overall intention is to provide a means for planners, managers, and policymakers to better understand the biological impacts already underway due to the changing climate. With this better understanding, we hope that decisions can be made to maintain or increase the health and diversity of our remaining forests in the eastern United States. Several National Forests are using these data to incorporate climate change analysis into their planning process. Some institutions are "planting ahead" by planting species slightly north of their current range. Our primary result, however, that we hope the world notices, is that these atlases show the value of a shift in carbon emissions to a lower path (B1 path or lower), so that the drastic species habitat changes projected under high emissions will never be realized.

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Tribal Salmon Restoration and Climate Change in the Pacific Northwest

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Tribes have lived in the Columbia River Basin for over 10,000 years. Long before written history, salmon (*Oncorhynchus* spp.) provided a unifying spiritual and economic force for the tribes. The tribes gathered at sites such as Celilo Falls on the Columbia River to share in alliance-forging harvests that exist to this day. A Celilo Fish Committee governed the fishery to ensure sharing, religious observances, and restraint in order to assure future salmon runs.

In 1855, the four Columbia River tribes, the Confederated Tribes of the Umatilla Indian Reservation, the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes and Bands of the Yakama Nation, and the Nez Perce Tribe, entered into treaties with the United States (United States 1855a, 1855b, 1855c, 1855d), ceding millions of hectares of their homelands and opening the basin to white settlement, while the United States pledged to honor their ancestral rights, including the right to fish and hunt in all of their usual and accustomed places. Unfortunately, hydroelectric and other development, habitat destruction, and overfishing have brought the salmon resource to the edge of extinction. Historically, annual salmon runs returning to the Columbia River Basin above the Bonneville Dam were estimated to have been in the range of 5–11 million fish. These runs have declined by over 90 percent, and currently 13 salmon and steelhead trout populations in the Columbia River Basin are listed under the Endangered Species Act.

The Columbia River Inter-Tribal Fish Commission (CRITFC) was founded in 1977 by the four treaty tribes. The organization provides coordination and technical assistance to the tribes in regional, national, and international efforts to protect and restore the fisheries and fish habitat.

Tribal fish and wildlife staff, along with CRITFC staff, developed a salmon restoration plan called *Wy-Kan-Ush-Mi Wa-Kish-Wit* (Spirit of the Salmon) (CRITFC 1995). Blending science with the wisdom and historical knowledge of the tribes, *Wy-Kan-Ush-Mi Wa-Kish Wit* is designed to restore fisheries in the Columbia River basin. The effort outlines the cultural, biological, legal, institutional, and economic context within which the region's salmon restoration efforts are taking place.

The tribes take a holistic gravel-to-gravel approach to salmon management that aims to increase survival at each stage of the anadromous life (Figure 1) by protecting, restoring, and managing the use of coastal and ocean resources through an ecosystem approach. The management goal is to restore a sustainable resource for the benefit of all peoples in the Pacific Northwest.