**LEFT:** Tucked up on the mountainside, this 11-tiered pagoda represents monasteries in the mountains of Japan.

**RIGHT:** Maple leaves cover the roof of the machiai house in the tea garden.

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**Aurora Santiago** is a nature and garden photographer whose work is strongly featured on the Seattle Japanese Garden website and blog. She won the People's Choice Award during the 2017 "Autumn Reflections" juried photo exhibit at the Japanese Garden. She is also a retired RN.

## PROJECTED ENVIRONMENTAL CHANGES IN THE PNW

- Rise of between 2.7°F and 10.4°F in mean air temperature this century, with greatest warming occurring in summer.
- Reduction in summer precipitation of up to 14% by end of century.
- Increase in mean winter precipitation of up to 8% by end of century.
- Summer soil-water availability likely to decline in much of region.
- This will lead to increased drought stress and reduced photosynthesis.
- Less precipitation will fall as snow, leading to reduced snowpack accumulation and duration, and subsequent impacts on dependent ecosystems.
- Warming winter temperature may lengthen growing season, promoting growth (given sufficient water).
- However, warmer winters may fail to satisfy "chilling requirement" of some species (e.g. Douglas-fir)—leading to delayed budburst and shoot growth.
- Also, early budburst may expose plants to potential frost damage.
- Early flowering may promote seed production but also lower reproductive capacity by altering synchrony between plants and their pollinators/dispersers.
- Elevated carbon dioxide in the air may enhance productivity and water-use efficiency in plants, offsetting somewhat the negative effects of warming.
- Warming climate will likely increase disturbances from wildfires, new pests and diseases, and invasive species.
- This may cause forests to convert from carbon sinks to carbon sources.

OUR CHANGING CLIMATE, PART 3

# Implications *for* Native Plant Communities *and* Conservation *in the* Pacific Northwest

BY NIALL DUNNE

Alpine meadow on Mount Rainier.
(Photo by Samuel Kerr/Wikimedia Commons)

*Part 1 of this article ("Bulletin," Fall 2015) discussed simple practices that gardeners can adopt in order to shrink their carbon footprint and help reduce the severity of climate change in our region. Part 2 ("Bulletin," Fall 2016) offered tips on how to adapt the garden to the coming conditions, which include hotter, drier summers; warmer, wetter winters; and new pest and disease problems (see "Projected Environmental Changes in the PNW," page 14). Part 3 explores the predicted effects of climate change on native plant communities in our region and the steps that land managers are taking to prepare.*

## ASSESSING VULNERABILITY

A few years ago, I went on a day trip to the Olympic Peninsula on behalf of the UW Botanic Gardens' Rare Care Program. The assignment was to find and survey a small population of golden chinquapin (*Chrysolepis chrysophylla*), a native tree in the beech family with leathery, evergreen leaves and spiny, chestnut-like fruits. The tree is relatively common in the coastal forests of Oregon and California, but only occurs in several small, scattered populations in Washington—the northernmost point of its current range.

It took some scrambling across a steep, forested ridge, but eventually my field partner and I found the trees—about eight of them. They were somewhat isolated from each other in a sea of western hemlock and Douglas-fir—and they didn't look particularly healthy. (The species is relatively intolerant of shade.) It was hard to imagine how this tiny population could persist over time. However, it's possible we may be hearing more from the species in the future. According to a 2012 USDA Forest Service report entitled "Climate Change and Forest Trees in the Pacific Northwest," "tree species that are highly drought-tolerant (e.g. Pacific madrone, golden chinquapin and Rocky Mountain juniper) may become more competitive in areas presently dominated by less drought-tolerant tree species."

The report assesses the vulnerability of regionally native tree species to climate change based on a number of factors, including their current distribution, adaptive genetic variation, reproductive capacity, and threats from insects and disease. In the Western Washington region, iconic forest species such as Douglas-fir, western red cedar, bigleaf maple and western hemlock all scored relatively low—meaning that they are at least risk from climate change effects. The highest vulnerability scores went to Pacific silver fir, subalpine fir, Engelmann spruce, noble fir and grand fir, which all happen to be cold-adapted, high-elevation tree species. (The report recommended that these species become a special focus for conservation and monitoring efforts.)

This tracks with general predictions about the influence of climate change on forests—namely that forest communities are expected to lose cold-adapted trees near their low-elevation and low-latitude range limits, while warm-adapted trees are expected to increase in abundance near their high-elevation and high-latitude limits.

## SPECIAL CONCERN FOR ALPINES

The concern for cold-adapted trees is echoed in a more recent Forest Service publication, "Climate Change Effects on Vegetation in the Pacific Northwest" (2014), which reviews and synthesizes the current scientific literature and ecosystem modelling projections on the topic. The authors found that of the five major biomes in the Pacific Northwest (subalpine forests and alpine meadows; maritime, coniferous forests; dry coniferous forests; juniper savannas and woodlands; interior shrub-steppe), subalpine forest and alpine meadows are at most risk. All the simulation models reviewed agreed that suitable climate available for most key subalpine species will be moderately reduced to nonexistent by the end of this century. Suitable habitat may only be available at high elevations in the far northern Cascade Mountains.

While many members of these high-elevation communities will likely be able to persist farther north of our region (either because they grow there already, or they may be able to migrate), some endemic alpine species—that is native alpines restricted to our region—may be in big trouble.

At the UW Botanic Gardens' 2018 Washington Botanical Symposium in March, Eric DeChaine, professor of biology at Western Washington University, presented his lab's research on five perennial herbs endemic to the Olympic Mountains: piper's harebell (*Campanula piperi*), Flett's violet (*Viola flettii*), Olympic Mountain groundsel (*Senecio neowebsteri*), Olympic Mountain synthyris (*Synthyris pinnatifida* var. *lanuginosa*), and Flett's fleabane (*Erigeron flettii*). DeChaine and his graduate student Samuel Wershow have estimated that 85 to 99 percent of suitable habitat will be lost for each of the species by 2080—and that small refugia (areas in which populations may persist as warming diminishes their habitats elsewhere) may only remain on the highest peaks of the eastern Olympics.

In a related paper published this spring in the "American Journal of Botany," Wershow and DeChaine write that all five species are habitat specialists occupying a narrow range of environmental conditions—generally the cold, rocky terrain on the snowy edge of the high alpine zone. "As temperatures warm and precipitation at high elevations shifts from snow to rain, these climate conditions will cease to exist. The endemics have essentially topped out; they are already occupying the highest and coldest available terrain, and there is no colder climate space available for their distributions to shift into as climate warms."

For a plan of action, the researchers recommend that potential refuge sites (some of which are mapped in their paper) be protected from non-climate related impacts, such as hiking by humans and foraging by non-native mountain goats. (Good news on the latter score: Olympic National Park officials began airlifting mountain goats back to their native range in the North Cascades this summer.)

So-called "interventionist" approaches, such as assisted migration (moving the plants to more favorable habitat), may also be helpful. However, Wershow and DeChaine say that these approaches are controversial due to their potential unintended effects on other native species and are unlikely to be used in the Park because it is managed as wilderness.

## OBSERVATIONAL STUDIES

Though the different ecosystem models seem to be in relative agreement about the vulnerability of alpine and subalpine communities, there's a lot of uncertainty about the other major biomes in our region. This stems from a lack of certitude about exactly what future growing conditions will look like (particularly precipitation levels), and also how plants will respond to the changes. For instance, some model results predict little or no change for maritime coniferous forests, while others predict reductions for this forest type—particularly in the southern part of the Pacific Northwest.

Models use simplified versions of natural systems and are best utilized as signposts rather than definitive forecasts. Other data, such as results from observational and experimental studies, should be factored in, too. One 2010 study of forest herb communities in the Siskiyou Mountains of southern Oregon was consistent with warming predictions: It found that, over a 60-year period (1949 to 2009), in which mean temperatures increased 3.5 °F, there were multiple changes in lower montane communities consistent with an effectively drier climate—including a reduction in plant leaf size and the presence of more plants from southerly climes.

The results of a similar, though shorter-term, 2015 study led by UW biology professor Janneke Hille Ris Lambers were not so clear cut, however. Her team examined the change in composition of six, old-growth stands of high-elevation forest at Mount Rainier National Park over the past 35 years in response to warming climate (mean temperatures have gone up 1.2 °F in the wider region since the 1900s). They didn't find much change in the overstory at all. However, they warned against interpreting the results as a sign that our forests are resilient to climate change. Instead they write about how changes in forest composition can lag behind changes in climate, due to the persistence of cold-adapted species (despite warming) and the limited ability of warm-adapted species to expand their ranges upward (despite newly suitable habitat)—it can take many years for trees at their upper range limits to mature and produce seed.

They also speculate that warming on Rainier may not have been as severe as the regional average. Projections for future climate change in our region are five to seven times greater than those observed in the last century—so it may just be a matter of time before we start seeing higher tree mortality and compositional turnover.

## MANAGING FOR UNCERTAINTY

Plant migration can be a very slow process. Because weather patterns change from year to year, plants have a lot of built-in adaptability, and trees can potentially survive for decades, even while severely stressed. They can also adapt to new climate conditions through generational evolution. The more variability in the genome of a species, the more likely that natural selection will produce offspring adapted to the changes.

Because of this, a lot of plant scientists think that major changes in our forests and other biomes will probably come about because of indirect effects of climate change—in particular major disturbances, such as wild fires and insect infestations. Climate change-related stress, such as drought, makes ecosystems more vulnerable to these disturbances. Fire and pests can eliminate weakened adult trees, providing opportunities for new species to move in—including invasive exotic plants, which are expected to become even more competitive as our climate warms up.

Higher year-round temperatures and decreased precipitation are already allowing pathogens to expand their ranges and growth rates in the western U.S. For instance, climate change is linked to large-scale destruction of forest by pine beetles in British Columbia, cytospora canker attacking thinleaf alders in the southern Rocky Mountains, and infestation of piñon and ponderosa pines by ips beetles in the Southwest.

Land managers in the Forest Service are being encouraged to prepare for such disturbances using a toolkit of "no regrets" approaches. These include maintaining and increasing biodiversity to make forests more resilient to drought and pests—if one species falls, there are others to fill the breach. Fire hazards can be reduced by such practices as prescribed burns and increasing tree diversity. Addressing existing problems, such as removing invasives, and restoring healthy native communities, can help mitigate future problems—even if it's unclear what these problems will be.

Monitoring will play a critical role, as scientists try to detect changes in plant species growth, reproduction, and mortality, and then figure out how to respond. Connecting the landscape through ecological restoration will be critical, too, to help plants disperse—once they start to move. We may have to become more flexible about restoring strict historical conditions, however. (The traditional goal of ecological restoration has been to restore plant communities to their pre-Columbian condition.) Species have varying degrees of tolerance for climate change, so when they do migrate, they will do so individually. In other words, climate change may produce novel vegetation communities. Our new forests may not look like the ones that colonial Americans encountered, but we can hope they will be healthy forests nonetheless.

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