REVISTING JOHN SAWYER AND DALE THORNBURGH'S 1969 VEGETATION PLOTS IN THE RUSSIAN WILDERNESS: A LEGACY CONTINUED

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Shortly after joining the faculty of Humboldt State University (HSU) in 1966, John Sawyer received a letter from one of America's leading evolutionary biologists and California floristic experts, G. Ledyard Stebbins. Stebbins suggested that John visit a remote place in the Klamath Mountains known as Blake's Fork to verify a report of one of California's rarest conifers—Engelmann spruce (*Picea engelmannii*). He encouraged John to record his findings in a new database called the *Inventory of Rare and Endangered Vascular Plants of California* organized by the California Native Plant Society. With conifers calling, John and his friend, fellow HSU professor Dale Thornburgh, began a journey that would change our understanding of conifer distributions, plant associations, and wilderness in California.

After a successful trip to Blake's Fork and the surrounding Salmon Mountains, John and Dale became enchanted with the region. They planned their next trip with hopes of finding more Engelmann spruce along Sugar Creek, just over the Salmon Crest from Blake's Fork. In the summer of 1968 they walked up Sugar Creek, documenting and collecting plants along the way. Wanderlust found them climbing the south-facing ridge above Sugar Lake, where they found foxtail pines (*Pinus balfouriana*), and into the Little Duck Lake Basin. At the southern end of the lake, Dale identified the first subalpine fir (*Abies lasiocarpa*) in California, although it took him half-an-hour to convince John! Around the campfire, maps came out and species lists were made. They determined that in a roughly drawn square mile—encompassing the ridges and valleys around Little Duck Lake—17 species of conifers could be found. The "Miracle Mile" was born (Kauffmann 2012).

John Sawyer (back) and Dale Thornburgh (front) climbing through chaparral near South Sugar Lake in the Russian Wilderness in summer 1969. Photograph by Steve Selva.

PRESERVING A BOTANICAL LEGACY

In the summer of 1969, John Sawyer and Dale Thornburgh began formal research in the "Miracle Mile" and the surrounding area. With the help of two undergraduate field assistants, Steve Selva and Dan Franck, they conducted over 200 vegetation surveys in the drainages surrounding Russian Peak and used that data to describe 15 California plant associations (Sawyer 2006, Sawyer 2007). These explorations led to a unique understanding of these forests and the revelation that preservation outside National Forest land was essential. Sawyer and Thornburgh's research was the basis for the preservation of the 12,000-acre Russian Wilderness in 1984. That area contains both the Duck Lake Botanical Area and the Sugar Creek Research Natural Area (RNA), which meet at the "Miracle Mile."

While Sawyer and Thornburgh recorded 17 conifer species in 1969, the 18th went unnoticed for 40 more years. In 2012 Richard Moore, a resi-

Richard Moore, a resident of Callahan, California and longtime explorer of the Klamath Mountains, discovered the elusive 18th conifer species—western juniper (*Juniperus occidentale*)—in the "Miracle Mile" 40 years after Sawyer and Thornburgh's expeditions. Mt. Shasta can be seen in the background. Photograph by Michael Kauffman.

dent of the town of Callahan just at the edge of the Russian Wilderness and lifelong explorer of the Salmon-Trinity Mountains, documented western juniper (*Juniperus occidentalis*) on a steep and scarcely traveled hillside near Sugar Lake.

In addition to the area being considered one of the richest assemblages of conifers in the temperate world, the "Miracle Mile" is also home to over 400 understory plants. This diversity exists because the Salmon Crest is the divide between the arid east side (which soon gives way to the Cascades and Great Basin) and the moister west side with a coastal maritime influence. The region is a crossroads where Great Basin species like western juniper mix with species that prefer a more temperate climate, such as Oettinger's trillium (*Trillium ovatum* subsp. *oettingeri*), California Rare Plant Rank 4.2.3.

RESURVEYING THE SAWYER-THORNBURGH PLOTS

In the spring of 2014 the Jules Laboratory at HSU received the unique opportunity to continue research in Sugar Creek, and continue the botanical legacy initiated by Sawyer and Thornburgh 45 years before. (Sawyer had died in 2012, and Thornburgh in 2013.) The project started as a partnership between HSU and the US Forest Service, with the goal of assessing ecological change in the Russian Wilderness, in particular the impacts of fire suppression and climate change on forest composition and structure.

Our team began by contacting John's wife, Jane Cole, and his best friend and fellow botanist, J.P. Smith, to help us track down the original Sawyer-Thornburgh datasheets and maps from 1969. With a little digging, they were able to uncover species lists and binders of original plot data along with our golden ticket: a hand-drawn map of plot locations. This data had to be digitized, so we

John Sawyer (left), Dan Franck, undergraduate field assistant (middle), and Dale Thornburgh (right) setting up camp in Etna, California, a town near the "Miracle Mile" in the Russian Wilderness, 1969. Photograph by Steve Selva.

Common understory plants growing in a seep near Little Duck Lake. TOP: **White marsh marigold (*Caltha leptosepala*) and mountain laurel (*Kalmia polifolia*).** BOTTOM: **Sierra laurel (*Leucothoe davisiae*), a common understory shzrub in moist red fir forests and seeps in the Klamath Mountains. Photographs by Melissa DeSiervo.**

began by scanning original maps, uploading them to ArcMap, and using computer software to align prominent features such as topographic lines and lakes with aerial imagery. We also found over 1,200 HSU Herbarium specimens collected by Sawyer and Thornburgh in 1969 that could assist us as a reference species list for the area.

In summer 2014 we set off on the first of approximately 25 trips to the Russian Wilderness over the course of two summers to relocate and resample the Sawyer-Thornburgh plots. With practice we fine-tuned our strategy for plot relocation by navigating to areas that matched the slope, aspect, and topographic position of the original plot descriptions. Then we searched for smaller-scale areas containing the conifer and understory plant species listed on the datasheet.

We were unable to verify exact plot locations because there were no field markers left from 1969. However, we limited our search window to 200 meters (or about 218 yards) from the hand-drawn map points, and only resurveyed plots that matched John and Dale's detailed descriptions. To collect data comparable to 1969, we mimicked the relevé plot protocol described in Sawyer and Thornburgh's report, which included percent cover of all trees in three size classes (overstory, saplings, and seedlings) as well as shrubs and herbaceous plants (Sawyer and Thornburgh 1977). We supplemented our historical data comparison with an extensive survey of individual trees, including detailed data on forest pathogens—something that was not done in the 1969 survey. In summer 2015 we began an additional project measuring the build-up of fuel loads around "legacy pines" (the larger sugar pines, *Pinus lambertiana*) to calculate litter and duff accumulation in lower elevation mixed conifer forests.

CHANGES IN FOREST COMPOSITION AND STRUCTURE

After two summers of data collection, we had successfully resampled 155 of the Sawyer-Thornburgh plots, measuring over 3,300 trees and recording hundreds of understory plant species. Our data analysis thus far shows a few important changes in forest composition and structure over the last 45 years. For example, we found significant increases in coverage of white fir (*Abies concolor*) throughout our study area, which is consistent with other historical resurvey projects in the Pacific Northwest (Dolanc 2012). Furthermore, our data shows that white fir (considered a fire intolerant species) is appearing at higher elevations than it was 45 years ago.

Aside from the few acres that burned in the 2014 Whites Fire, the majority of the Russian Wilderness has not experienced a large-scale wildfire in over 100 years. Historically, the Klamath Region is described as having had a mixed-severity fire regime, with a fire return interval of about 15 years in lower elevation mixed conifer forests (Taylor and Skinner 1998, 2003). Based on these estimates, lower elevation forests in the Sugar Creek basin have missed anywhere between three and six fire cycles, which has led to a dense overcrowding of fire-intolerant taxa such as white fir, and to a lesser extent in this region, Douglas-fir. Other tell-tale signs of fire suppression in this region include heavy accumulations of litter and duff around large pines, and conifer encroachment into upper montane and subalpine meadows.

Original plot datasheet from 1969 research expedition to the "Miracle Mile." Photograph by James Adam Taylor.

MORTALITY OF SHASTA RED FIR

Shasta red fir (*Abies magnifica* var. *shastensis)* inhabits the upper montane and subalpine zones of southwestern Oregon and northwestern California (Shasta, Siskiyou, and Trinitiy Counties) and is considered a hybrid between California red fir (*Abies magnifica* var. *magnifica*) and the more northern species, noble fir (*Abies procera)* (Mathiasen and Daughherty 2008).

Several recent studies in the Pacific Northwest have shown declines in California red fir (Bulaon and Mackenzie 2007, Mortenson 2011). In addition, annual aerial detection surveys that the USDA has conducted from 2009 to the present in Northern California have revealed significant mortality in both Shasta and California red fir (Heath et al. 2009, 2013).

Many Shasta red fir stands in the Russian Wilderness show signs of true fir dwarf mistletoe (*Arcethobium abietinum*) infestation and cytospora (fungal) cankers causing crown dieback. Within a few years most of the trees in these highly affected stands will die. • INSET: True fir dwarf mistletoe is a native parasitic plant that extracts water and nutrients from its host and can cause considerable stress on the tree. Approximately one-fifth of the live Shasta red firs sampled in 2014 and 2015 contained mistletoe infestation. Photographs by Melissa DeSiervo.

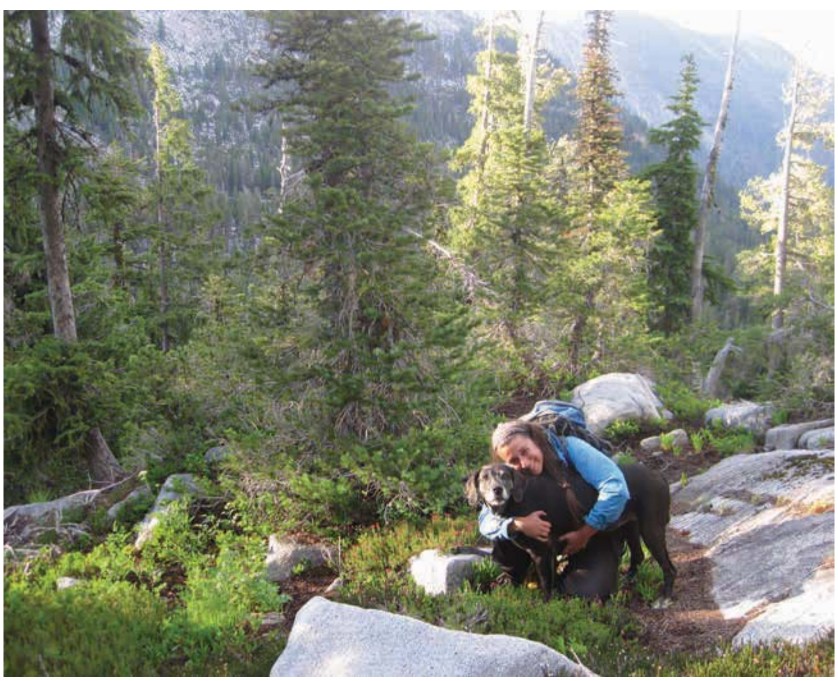
Red fir decline is generally attributed to a complex array of climatic factors such as decreased snowpack and warmer temperatures that trigger increases in native pathogens. These include dwarf mistletoe (*Arceuthobium* spp.), canker-forming fungi (*Cytospora* spp.), root diseases (*Heterobasidion annosum*, *Armillaria ostoyae*), and fir engraver beetle (*Scolytus ventralis*). Dwarf mistletoe and *Cytospora* infection frequently occur in combination, with signs and symptoms of unhealthy trees including tumefactions (swelling of branches) and brooming (dense aggregations of abnormal branch and twig growth), and flagging (dead branches). In highly affected stands, there is often significant canopy dieback and many trees with dying and/or dead tops.

Trees that are drought stressed and/or contain other pathogens are often attacked and killed by fir engraver beetle. Signs of fir engraver attack include "buckshot" holes in the bark (exit holes of adult beetles) and substantial pitching on the bole (main stem) of the tree. In stands with significant mortality, many downed logs and branches will contain the distinctive fir engraver beetle galleries, and many dead trees will sprout fruiting bodies of the fungi *Cryptoporus volvatus*.

ABOVE: Fir engraver beetle (*Scolytus ventralis*) infestation is largely responsible for the ongoing mortality event of Shasta red fir in the Russian Wilderness, and the beetle's gallery patterns can be seen on many standing dead trees and fallen logs. The adult female beetle bores a thick, horizontal gallery and lays her eggs in the perpendicular side galleries, creating a distinctive pattern that is distinguishable from other bark beetle species. • RIGHT: Another indication of bark beetle induced mortality is the white round fruiting bodies of the fungi *Cryptoporus volvatus* on standing dead trees and logs. The fungus spores are carried into the tree by bark beetles and woodborers and help to decay the sapwood of the tree that has been killed by bark beetles.

Humboldt State University researchers Drew Bost, Stefani Brandt, Emily DeStigter, and Melissa DeSiervo near Bingham Lake in 2014. They were part of the team that resurveyed vegetation work done 45 years earlier by John Sawyer and Dale Thornburgh. Photograph by a friendly, but nameless, hiker.

Another pivotal finding of our research thus far is a current, large-scale mortality event for Shasta red fir (*Abies magnifica* var. *shastensis*). Over the course of two years, we sampled over 700 Shasta red fir trees across the Russian Wilderness of which approximately one-quarter were dead, and one-third were categorized as "unhealthy" or "sick" based on signs and symptoms of forest pathogens such as dwarf mistletoe, fir engraver beetle, and probable *Cytospora* (fungal) infection (see sidebar). We believe that these native pathogen outbreaks are strongly tied to the increasingly warmer and drier climate, which is making trees more water stressed and thus less resistant to pathogens. We hypothesize that Shasta red fir is a particularly vulnerable species because it inhabits the "upper montane zone" and is heavily reliant on snowpack, which has decreased dramatically over the past 15 years. Again, the lack of fire leading to dense overcrowding throughout this region may be another reason why usually innocuous pathogens are now having a deleterious effect on forest stands.



Humboldt State University graduate Melissa DeSiervo, and canine assistant Tundra, collecting data in a subalpine fir stand in 2014. Photograph by Drew Bost.

FUTURE WORK

The Russian Wilderness is subject to the complex threats of global climate change, and our research aims to describe how the ecology of this biodiversity hotspot is shifting. Using the Sawyer-Thornburgh historical dataset, we have been able to detect some important changes in forest composition and structure in this diverse area over the past 45 years, including an increase in a fire-intolerant species, white fir, and an extensive mortality event for a drought sensitive, higher elevation species, Shasta red fir. In addition to digging deeper into our tree dataset, we are currently in the process of analyzing the historical and present understory plant data and expect to publish our findings soon. We hope that this work will advance a botanical legacy and establish a pre-eminent understanding of one of the most species-rich temperate coniferous forests on Earth.

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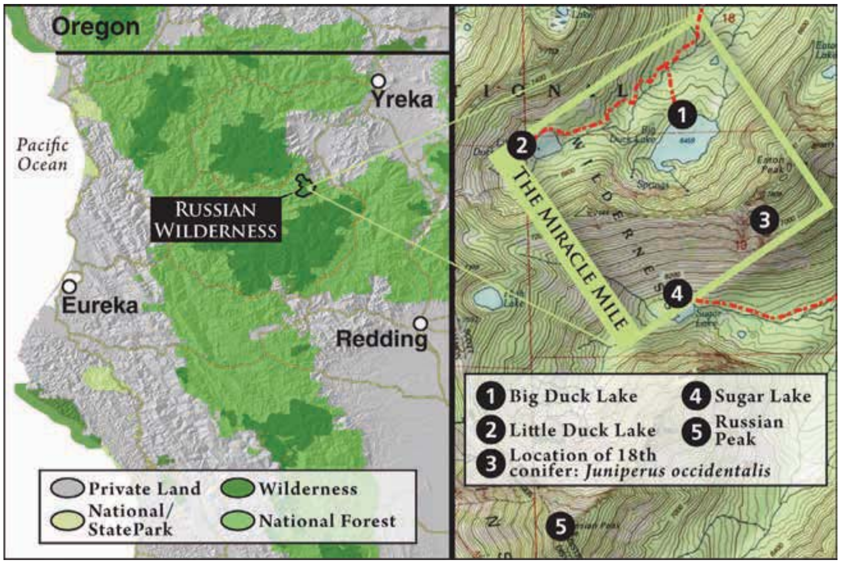
FIGURE 1: THE "MIRACLE MILE"



Location of the "Miracle Mile" within the Russian Wilderness, a biodiversity hotspot first discovered by Humboldt State University professors John Sawyer and Dale Thornburgh in 1969.

Source: Michael Kauffmann, 2015.

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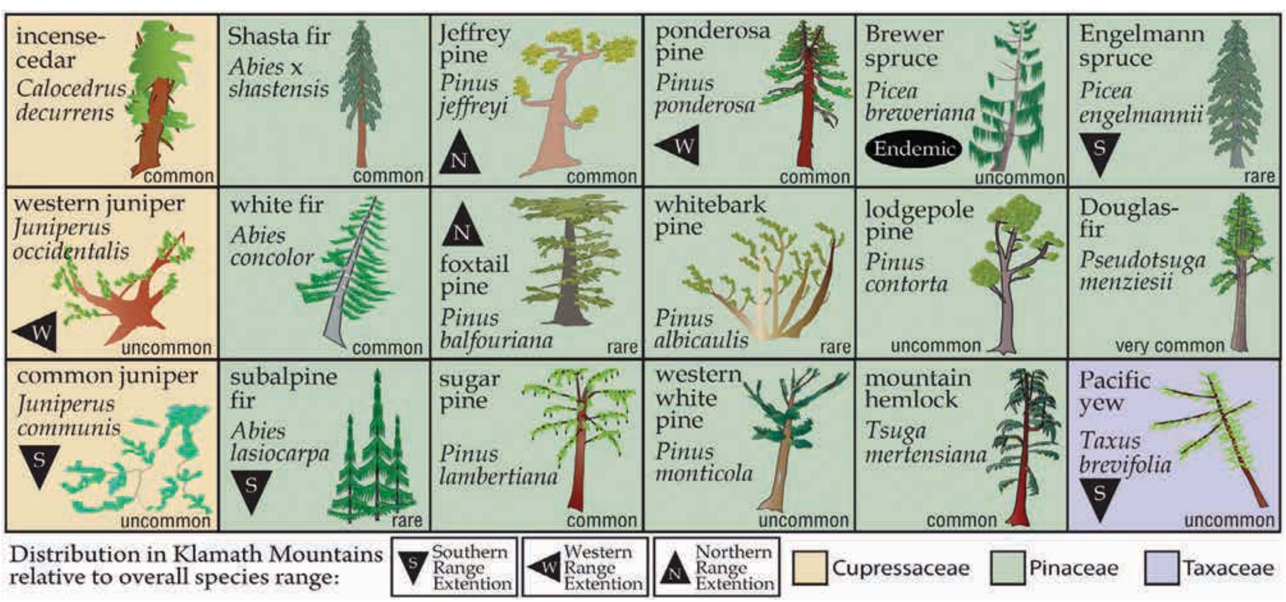
FIGURE 2: CONIFERS OF THE "MIRACLE MILE"



The "Miracle Mile," a square mile area located in the Russian Wilderness in the Klamath Mountains contains 18 species of conifers, the highest diversity of conifers on record anywhere in the world.

SOURCE: Michael Kauffmann, 2015.