Issue 18 • Fall 2025

The Learning Forest

Sharing scientific knowledge on sustainable land management in the Olympic Experimental State Forest and beyond

From the Editorial Board

Managing forests with knowledge and care is the theme of this issue of The Learning Forest. The featured article demonstrates this commitment on lands managed by the Washington Department of Natural Resources (DNR) and the guest article on lands managed by **EFM Investments & Advisory.**

In the featured article, DNR describes its new, innovative model to identify structurally complex forest across millions of acres using data from its remote sensing forest inventory system (RS-FRIS). The model was developed with ecological knowledge on stand development, technological advancements in remote sensing and computer modeling, and a remarkable amount of field training data. The model is rigorous, repeatable, and approximately 81 percent accurate. It is already being applied to estimate the extent of structurally complex forests on DNR-managed lands in Western Washington, including in the Olympic Experimental State Forest.

In the guest article, forestland investment management company EFM Investments & Advisory discusses management of their recent acquisition: 68,000 acres of private land on the western Olympic Peninsula. Their management approach combines higher tree retention, planting without herbicide application, longer rotations, and active restoration with conservation easements and carbon offtake agreements, all in the context of strong, mutually beneficial partnerships.

Good stewardship of forest ecosystems requires an informed, thoughtful, and holistic management approach. Claims for sustainable stewardship abound but often are not supported by actions. The two articles in this issue are examples of good stewardship. We hope you enjoy reading about them.

What's Inside?

Featured Article

Guest Article

Photo 1. DNR staff collecting data for the Structurally Complex Forest Detector model, highlighted in this issue's featured article. DNR staff photo.

Featured Article

Detecting Complexity

Building DNR's Structurally Complex Forest Detector Model

By Cathy Chauvin, DNR

In 1900, foresters doing planning relied largely on paper maps and ground surveys.

Fast forward to January 2025, when Washington Department of Natural Resources (DNR) staff set out to assess the extent and distribution of structurally complex forest on lands it manages west of the Cascade Crest in Washington. Called the Landscape Assessment, this project would gauge DNR's progress toward specific policy goals in its **Policy for Sustainable Forests**.

DNR has been mapping forests for decades using ever-evolving techniques. For this project, DNR staff saw an opportunity to develop an idea they had been exploring for some time: training a model to identify structurally complex forest using data from DNR's remote-sensing forest inventory system (RS-FRIS). Developed by correlating sensing information with field-collected data, RS-FRIS includes tree height and diameter, trees per acre, and other forest inventory attributes.

If the model worked, DNR would be able to map structurally complex forest across a million plus acres with a high level of accuracy. Appropriately named the Structurally Complex Forest Detector, it represents a long, long walk from paper maps.

Form and Function

Like people, forests do not all develop in the same way or at the same rate. Nature is messier than that. Yet humans need to classify forests to understand them better and manage them effectively. To meet this need, scientists describe forest development as a series of stand development stages.

DNR uses a series of stages derived from **the work of Northwest ecologist Jerry Franklin** and modified by another Northwest ecologist, Robert Van Pelt (Figure 1). Each stage is defined largely by changes in forest composition, structure, and processes.

One of these stages is Maturation II. At this stage, most of the trees are approaching their maximum height, and the canopy has thinned enough to allow some light to reach the forest floor. Below their crowns, some of the overstory trees have branches called epicormics, which grow from dormant buds beneath the bark when a newly created gap in the canopy exposes a bare portion of the trunk to light (Photo 1). Beneath the upper canopy is a second canopy layer of younger, shade-tolerant trees (Photo 2).

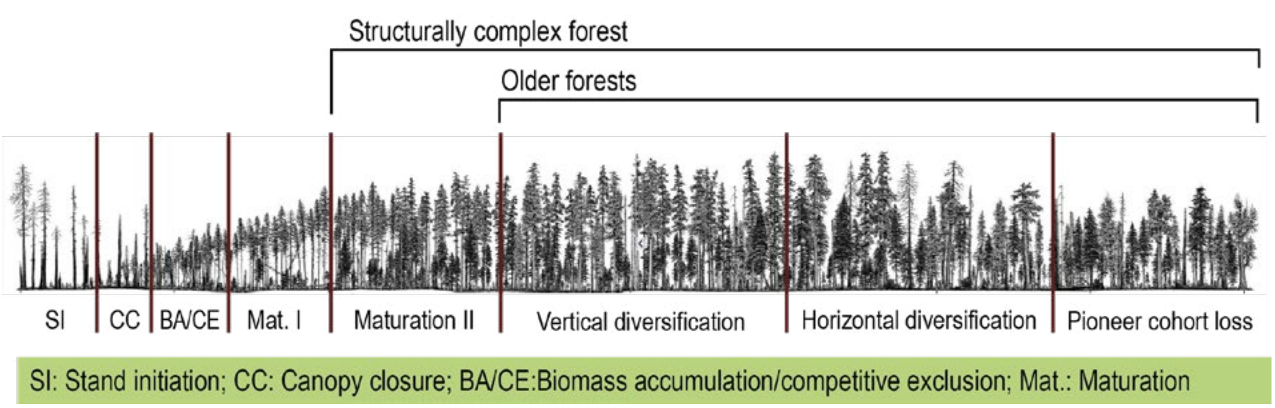

Figure 1. DNR's system of stand development stages. Structural complexity begins at the Maturation 2 stage and continues through the final stage, pioneer cohort loss. Older forests are those in the final three stages of development. Drawing by Robert Van Pelt, reproduced from Jerry Franklin's work on stand development stages.

Photo 1. Epicormic branch. These branches can be oddly shaped, and only form on some species of trees, including Douglas fir. DNR staff photo.

Photo 2. A forest in maturation II, with large trees and a developing understory. DNR staff photo.

DNR considers forests in Maturation II or later developmental stages to be structurally complex. These forests matter for a number of reasons. "Habitat function is tied to structure, and complex forests have more function to support a greater diversity of organisms," explains DNR natural resource scientist Dan Donato. Structurally complex forests also store significant amounts of carbon and provide other essential ecosystem services.

Into the Rain

The core team for this project was led by Kate McBurney, an information technology project manager. It included two natural resources scientists, Dan Donato and Josh Halofsky, and two remote sensing and GIS specialists, Ethan Hughes and Allison Bailey.

Dan's job was to organize the field effort. To train the model and assess its accuracy, the team needed to know the stand development stage of representative survey plots across a very large and diverse project area. "We established survey plots across forest types, elevation, and site productivity," says Dan (Figure 2). They were also careful to choose plots that ran the gamut of stand development stages. In total, "we established over 2,200 plots, which is amazing. Most ecological studies rely on a few dozen," he said.

Each survey plot was a 2.5-acre circle. Within these plots, staff set a central GPS point and then assessed the stand development stage using a classification key developed by Robert Van Pelt in his book **[Identifying Old and Mature Forests in Western Washington](#).**

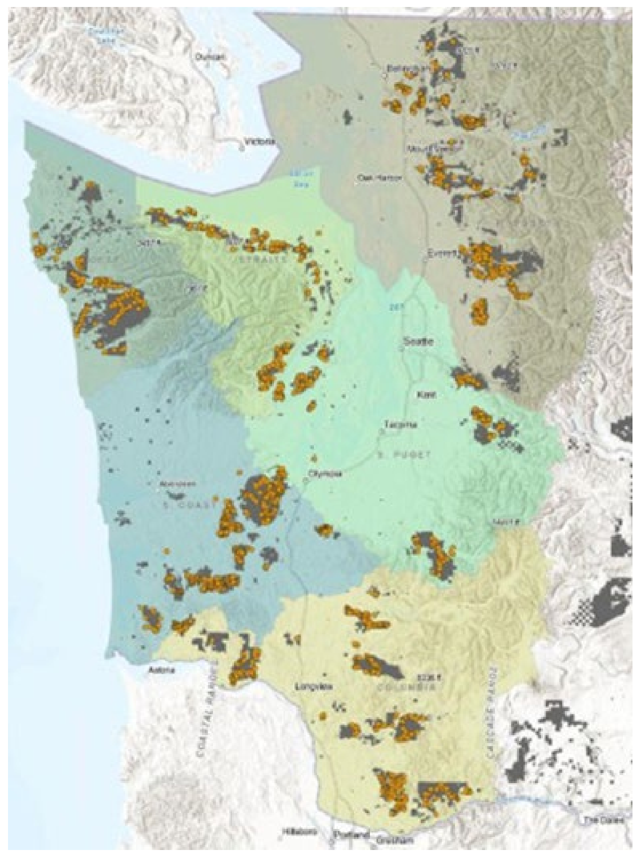

Figure 2. Geographic distribution of the 2217 field plots. Lands managed under the HCP are broken into six units, shown as shaded areas on the map. DNR-managed forestlands within each HCP unit are depicted in dark gray.

The bulk of this work was done in the cold, wet months of February and March by highly trained field staff from DNR's region offices. "Cooperation between our team and the regions made the project a lot easier," said Kate. "We were fortunate, everyone we needed was available to help."

Dan and a handful of others also re-visited about 10 percent of these survey plots to independently verify the forests' development stage and whether the stand was structurally complex. Overall mean accuracy between initial and subsequent observers was high: 89 percent for the developmental stage, and 96 percent for structural complexity.

Developing the Model

The model for this project was based on a statistical technique called logistic regression. This technique is used to answer a binary (yes or no) question based on certain variables. For example, a logistic regression model can predict if someone will default on a car loan based on income and credit scores, or in this case, whether a forest is structurally complex or not based on RS-FRIS attributes like tree diameter.

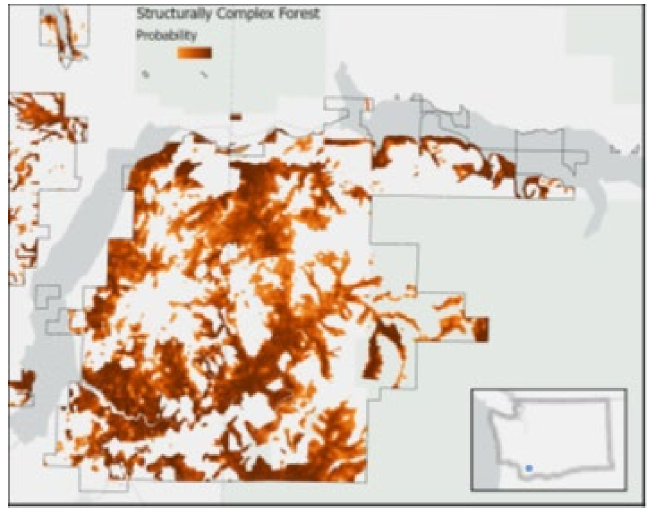

Figure 3. Sample map of structurally complex forest in southwest Washington. The darker the color, the higher the probability that the forest is structurally complex.

But which attributes? RS-FRIS has over 40 that could be used as variables in the model. To narrow them down, the team had four requirements. The variables should be distinct from each other, based on DNR's definition of structural complexity, and effective for the task at hand. In addition, the variables should be compatible with growth and yield models that project forest development into the future.

Through extensive testing, the team selected two: number of canopy layers and quadratic mean diameter (QMD) 6. QMD is a type of average tree diameter that gives more statistical weight to larger trees, and QMD 6 is specific to trees greater than six inches in diameter at breast height.

Just having the right variables was not enough, however. To predict whether the forest is structurally complex or not, the model also needed the average value for each variable. For example, how many canopy layers do structurally complex forests have? The team determined these values through statistical analysis.

Once these parameters were identified and incorporated into the model, it was run on RS-FRIS data for the entire project area.

Anyone who has hiked through the forest knows how much it can vary from one area to the next. To handle this, the model moves from one tenth-acre square to the next until it has covered the entire project area. Each time it stops, it makes another prediction. "It's like the model is walking through the woods," explains remote sensing specialist Ethan Hughes. "The result is a smooth transition across the landscape between forests that are and are not structurally complex" (Figure 3).

In final testing, the model had an accuracy of roughly 81 percent. "It's not perfect, but it's right four times out of five," said Ethan. That is remarkable, considering that the model was built in just four months, including extensive fieldwork in the dead of winter.

While developing this model, DNR also tested a detector model for older forests, which are forests in the final three stand development stages (Figure 1). The accuracy of this model was still good but lower, roughly 70 percent. "The transition from younger stands to Maturation I is pretty clear, but the transition from Maturation II to later stages is a lot more subtle and harder to capture," explains Kate. The older forest model was not used for the Landscape Assessment.

Next Steps

DNR staff will continue to gather more data to improve the model's accuracy. For example, foresters planning timber sales or gathering data for RS-FRIS will perform surveys to make stand development calls. "As we get more data, we will revamp the model, and possibly incorporate more variables," mentions Kate. They will also continue working on an older forest detector model.

In the meantime, they wrote **a detailed report** on their efforts which is already sparking interest. "Using our report, people can recreate what we did. And they're curious about it," says Kate.

As well they would be. This project demonstrated that a forest inventory system built with remote sensing data can be used to model structurally complex forests. Why is that significant? Because DNR's remote sensing data is collected via aircraft, not from the ground. "And everything that makes a forest structurally complex is beneath the canopy, hidden from above," Kate explained. ☙

About Kate McBurney

Kate McBurney has a Master of Science in Forest Resources from the University of Washington. She has worked for the University of Idaho, a U.S. Forest Service Research Station, and a timber investment organization, and has served as project manager for DNR's Forest Informatics section for the past four years. Specializing in forest analytical work in biometrics and forest planning, she produces well-documented and researched projects and technical products that provide value to DNR and beyond. She can be reached at **kate.mcburney@dnr.wa.gov**.

Recent Publications

Martens, Kyle D., and Warren D. Devine. 2025. Stream Temperature, Density Dependence, Catchment Size, and Physical Habitat: Understanding Salmonid Size Variation Across Small Streams. Fishes 10, No. 8: 368.

This paper examines how the average body size of juvenile salmonids (coho and cutthroat trout) in small streams is influenced by stream temperature, catchment size, physical habitat, and fish density in the streams. Juvenile salmonid body size plays a pivotal role in shaping life history trajectories and survival. Contrary to expectations, salmonid density, catchment size, and physical habitat metrics contributed more to the top models than stream temperature metrics. A better understanding of factors affecting body size will help inform appropriate habitat conservation efforts. Management or restoration actions aimed at improving or preventing anticipated declines in physical habitat, such as adding in-stream wood or increasing pool area, have the potential to ensure a natural range of salmonid body sizes across watersheds.

Frank, G. S. and J. W. Rivers. 2025. Population Responses of a Native Solitary Bee to Select Prescriptions in the T3 Watershed Experiment, Olympic Experimental State Forest. Study Plan.

This study will quantify the demographic response of a native solitary bee (*Osmia lignaria*), in stands harvested under select upland management prescriptions as part of the Type 3 (T3) Watershed Experiment, including the Complex Early Seral and Variable Retention Harvest prescriptions. The results of this study will provide managers with a better understanding of how alternative silvicultural practices may influence pollinator habitat quality. The monitoring approach includes 1) Installing wooden blocks containing nest cavities preferred by this species at sampling stations in post-harvest stands; 2) Releasing a fixed number of adult bees alongside nest blocks to ensure that reproductive outputs, including total offspring, offspring sex ratio, and overwinter survival, reflect foraging habitat quality at sampling stations as closely as possible; and 3) Quantifying floral density and flowering species richness in transects at nest sites. A pilot project conducted from April to June 2025 proved the feasibility of the monitoring approach. Future monitoring will depend on available funding.

Guest Article

Climate-Smart Forestry: a Mechanism to Improve Long-term Forest Value, Profitability, and Community Benefits

By Bettina von Hagen, EFM Investments & Advisory

In late 2024, Portland-based **EFM Investments & Advisory** (EFM) purchased 68,000 acres of rainforest on the western Olympic Peninsula from global forest company **Rayonier** (Photo 1 and Figure 1). Comprising most of the private land south of Lake Ozette and north of the Clearwater River, this acquisition includes the former Rayonier headquarters and the Bogachiel Rearing Pond managed by Washington Department of Fish and Wildlife.

EFM is an independent, for-profit, employee-owned forestland investment management company founded in 2004. Since inception, EFM has focused on developing climate-smart forestry approaches that combine timber production with carbon sequestration, biodiversity conservation, recreation, and community partnerships.

EFM raises capital through pooled funds from a range of high-net-worth and institutional investors, and purchases forests that are well suited for its management approach. One criterion is the adjacency of public and conservation lands where its management objectives can be strengthened and amplified, and where landscape-scale restoration is possible.

This latest acquisition is intermingled with lands managed by the Washington Department of Natural Resources (DNR) within the Olympic Experimental State Forest. It is adjacent to Olympic National Park along most of its western border (Figure 1), which in turn is adjacent to the Quillayute Needles National Wildlife Refuge and the Olympic Coast National Marine Sanctuary. Most of the property lies in the Quillayute watershed, but it also contains important coastal watersheds. The property is critical to salmon recovery, especially coho, given the abundance of low-gradient stream habitat.

Photo 1.Aerial view of the purchased property, with Olympic National Park and coastal islands in the background. Photo by Betinna von Hagen.

This acquisition, plus 27,000 acres already held by EFM on the Olympic Peninsula, comprises nearly half of the 200,000 acres in Washington, Oregon and California managed by EFM. This geographic concentration highlights the compelling investment characteristics of the Peninsula, which include timber infrastructure, high growth rates and low fire risks that boost carbon accumulation, significant salmon streams with restoration potential, and the presence of Tribes, highly competent non-profits, and public agencies deeply invested in the well-being of the Olympic Peninsula landscape and communities.

Achieving a Desired Future Condition

EFM manages forests for their whole range of values, with the fundamental belief that managing for whole systems yield higher and more enduring financial, ecological and social values. EFM's goal for this acquisition is to achieve a desired future condition within an investment context. This condition includes higher stocking, more structural complexity, and greater age and species diversity, which should lead to more carbon accumulation, higher quality timber over time, and enhanced habitat.

To increase wood quality and carbon sequestration, EFM extends harvest rotations where feasible, which results in higher log value and reduced costs as more saw log volume is produced per acre. EFM also uses commercial thinning to improve log quality and transform young, dense forest stands into more productive and healthier forests (photos 2 and 3). In addition to increasing stand growth, thinning improves forest health and resilience,

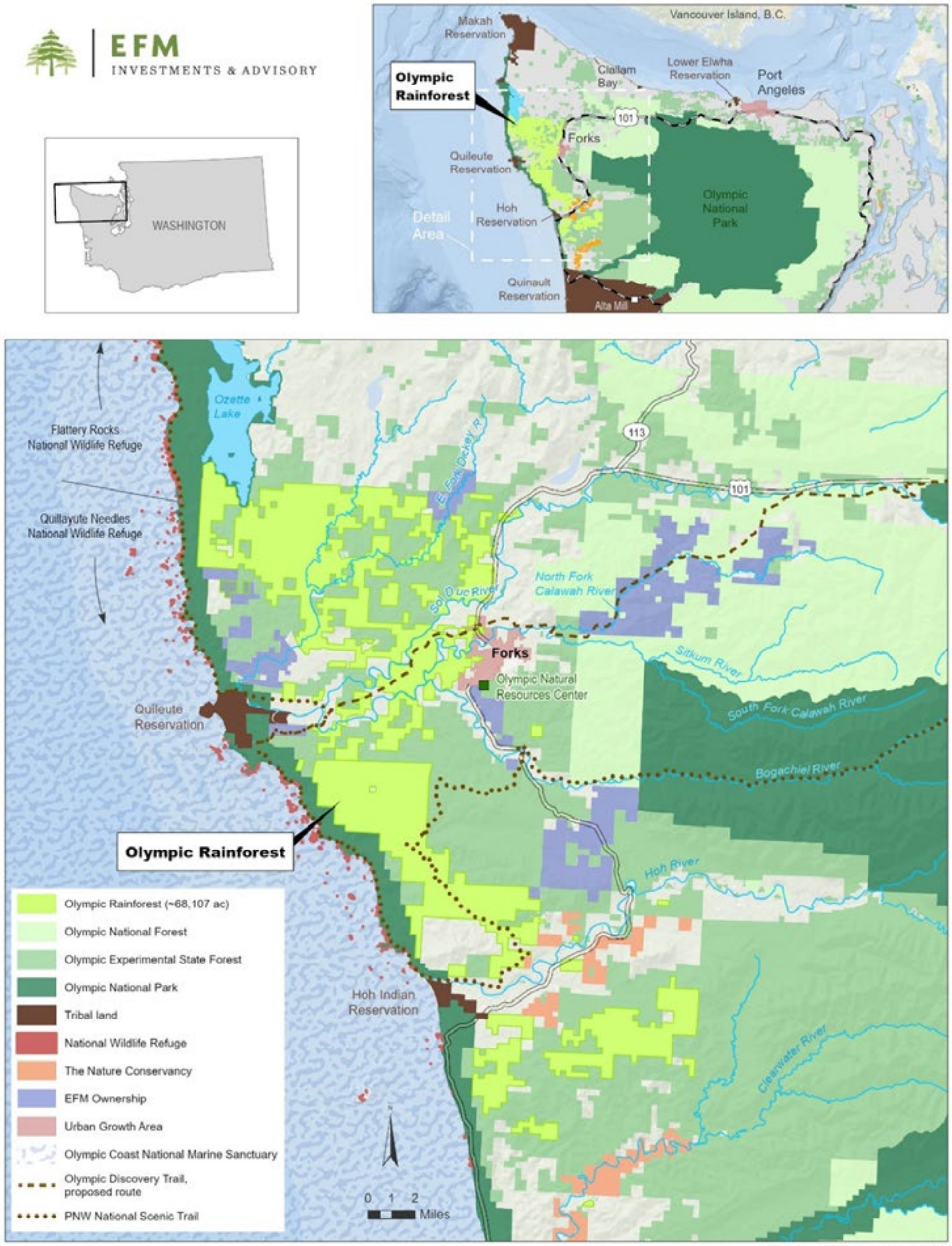

Figure 1. Map of the 68,000-acre Olympic Rainforest acquired by EFM from Rayonier in late 2024 (shown in lime green). Previously acquired properties are in purple. Property management is done by Forks-based Pacific Forest Management, with whom EFM has been working for over two decades.

Photo 2 (left) and 3 (right). Photo 2 shows a commercial thinning operation to reduce tree density, which improves forest health and focuses resources on the remaining trees. Laying down slash and branches on the forwarder's tracks protects soil and retains nutrients. Photo 3 is an aerial view of the stand after thinning. Photos by Brett McGinley.

promotes a diversity of plant species in the understory, and encourages wildlife use.

To improve habitat and increase species diversity, EFM retains individual trees and groups of trees in harvest units and introduces western red cedar, along with other underrepresented species such as silver fir, when replanting.

EFM also focuses on early seral habitat, recognizing the importance of flowering shrubs and abundant herbs in the early seral stage for pollinators and migratory birds, among other animals. For example, EFM does not use herbicides during stand establishment. EFM plants harvest units as quickly as possible to reduce competition with planted conifers, and only uses herbicides to control invasive species when no other practical method can be used.

Protecting and enhancing long-term soil productivity is also a priority. EFM pursues this goal by prohibiting log skidding, limbing trees in the unit rather than at the landing, and intentionally retaining downed logs.

Partnerships, Access, and Financing

This acquisition lies in the ancestral homelands of the Quileute and Hoh Tribes. In place since time immemorial, Tribes have significant knowledge and interest in management. EFM is developing agreements with Tribes on cultural harvesting, salmon restoration, science and monitoring, and other tribal priorities.

EFM also seeks to partner with the private and public sector to increase the flow of benefits of this property to local communities, including development of new wood-based businesses and non-timber forest products; restoration of riparian and upland areas; redevelopment of the 20-acre, former Rayonier headquarter facility; and other community priorities. Redevelopment could add to the growing infrastructure in and around Forks for wood processing and related activities. These actions demonstrate EFM's deep commitment to maintaining and enhancing logging, hauling, and milling infrastructure, and working with public agencies and the private sector to strengthen existing infrastructure and develop value-added opportunities.

Another key goal is to improve public access and recreation through a conservation easement and to continue development of two regional trails on the property: the Olympic Discovery Trail (linked to the national Great American Rail Trail) and the Pacific Northwest Regional Scenic Trail, a companion to the Pacific Crest Trail. EFM currently provides free, non-motorized public access and motorized access on select roads.

To help finance the transition to a forest with higher stocking, EFM entered into ten-year carbon offtake agreements with Microsoft and Meta. Under these agreements, Meta and Microsoft will acquire a portion of the credits associated with the Olympic Rainforest carbon project. These carbon credits will meet a high standard of additionality, meaning they will be generated above and beyond common industrial practices in the region and beyond what is required by regulations. The project will be verified by independent, third-party auditors, who will assess compliance with the methodology, including important carbon project quality standards such as additionality, permanence, and leakage.

EFM is honored to manage this ecologically, financially, and socially important property. We welcome collaboration with DNR and other parties to help contribute to the knowledge and stewardship of this important ecosystem. ☙

About Betinna von Hagen

Bettina von Hagen is the co-founder, CEO, and Board Chair of EFM Investments & Advisory. A former vice president of Ecotrust's Natural Capital Fund and commercial banker, Bettina has over 30 years of experience in forestry, conservation finance, impact investing, commercial banking, and investment fund management. She also has significant expertise in ecosystem service markets, including both carbon and biodiversity, and serves as the co-chair of the Forest Trends Board of Directors and the forestry representative to the Oregon Climate Action Commission. She can be reached at **bettina@efmi.com**.

Project Updates

Type 3 Watershed Experiment

The **Type 3 (T3) Watershed Experiment** is a roughly 20,000-acre management experiment that is being implemented across 16 watersheds in the Olympic Experimental State Forest (OESF). Its purpose is to test novel land management strategies that benefit both communities and forests. For background, **visit the Washington Department of Natural Resources (DNR) website** or **the project webpage**.

Timber Harvests

All 13 timber sales implementing the T3 Experiment on 2,194 acres have been logged in compliance with the research design, as verified through compliance monitoring. With effort and creative thinking, timber sale purchasers and loggers successfully navigated many challenges posed by the novel prescriptions, such as more and scattered leave trees, thinning in steep riparian areas, and creating logjams in streams (Photo 1).

Photo 1. Advanced Variable Density Thinning prescription implemented in a T3 Watershed Experiment timber sale, showing a thinned area and a gap (front of photo). Sitka spruce and western redcedar will be planted in the winter of 2026. DNR staff photo.

Silviculture

The silviculture part of the T3 prescriptions follows **detailed silviculture implementation plans**. These plans guide site preparation (application of herbicides before tree planting) and tree planting and tending for each prescription. The plans are being implemented by DNR's Olympic Region Silviculture Program, with consultation from T3 researchers.

In summer of 2025, University of Washington (UW) interns completed site preparation on most of the units that will receive the Ethnoforestry Variable Density Planting (EVDP) prescription (Photo 2). Tree planting will start in January 2026. Refer Education and Outreach on page 11 more information.

Photo 2. A PVC pipe and paper plate marking the center of a tree clump to be planted for the EVDP prescription. Visible on drone imagery, the paper plate will mark an exact location for remote sensing modeling and monitoring. DNR staff photo.

Hardworking Olympic Corrections Center crews have built three, 8-foot deer fences around one-acre test plots for a T3 Watershed Experiment sub-study on regenerating western redcedar (Photo 3). These fences are meant to deter deer and elk browsing. The final fence will be built in December, and all four test plots will be planted in winter 2026.

Photo 3. A fence built to deter deer and elk browsing in a 1-acre test plot in the redcedar regeneration sub-study. DNR staff photo.

Projecting Forest Conditions, Timber Volume, and Revenue

All areas planted with novel T3 uplands prescriptions will be harvested between 2066 and 2096. Since revenue is expected to vary by prescription, growth and yield projections are essential. UW researchers **made the first projections** using the **Forest Vegetation Simulator** in

2024 and JMurray Forestry completed the second projections using the Forest Projection and Planning System (FPS) in June 2025. The FPS model incorporated implementation costs and assumptions for future timber values, and also projected economic outcomes for each prescription. T3 researchers will compare projections from the two models, consider reasons for differences, and identify needed economic analyses.

Monitoring

After several years of pre-harvest monitoring in riparian and upland units, T3 researchers are now concentrating on post-harvest monitoring. Riparian indicators include fish, macroinvertebrates, periphyton, leaf litter, light, in-stream wood, water temperature, and water chemistry. Upland indicators include forest birds, woodland salamanders, mammals, and vegetation.

In the spring of 2025, researchers from Oregon State University conducted a pilot project and completed a study plan for monitoring bee response to standard and novel prescriptions in the T3 Watershed Experiment (Photo 4). Refer to "Recent Publications" for more information.

Photo 4. Forest bee nest block showing the white tube that contained the bees (top) and several completed nest tunnels. This photo was taken five weeks after installation in an area harvested using variable retention.

Status and Trends Monitoring of Riparian and Aquatics Habitat

In 2013, DNR implemented a long-term monitoring program in the OESF to document the status and trends of riparian habitat conditions under management guided by the State Trust Lands Habitat Conservation Plan. Visit this link for 2013 to 2020 results.

One of the nine habitat indicators monitored by this program is stream temperature, which DNR has been measuring year-round in Type-3 streams. In the summer of 2024, DNR strategically reduced the number of streams monitored year-round from 50 to 28 and added a new monitoring approach: monitoring summer stream temperature once before and at least two summers after a variable retention harvest, upstream, adjacent to, and downstream of the harvest.

To date, DNR has collected one summer of pre-harvest data and one summer of post-harvest data for four of the timber sales, and one summer of pre-harvest data for four additional sales. Data will be used to measure whether the timber sales have an influence on stream temperature, and if so, whether that influence extends downstream of the harvest.

The Learning Forest is an electronic, biannual newsletter published jointly by the Washington Department of Natural Resources (DNR) and the Olympic Natural Resources Center (ONRC).

All newsletter issues are available online. To receive this publication or to be added to the distribution list, visit our sign-up page or contact the editor at Cathy.Chauvin@dnr.wa.gov.

Education and Outreach

Field Tour

On September 11, 2025, the Washington Department of Natural Resources (DNR) hosted a field tour of the T3 Watershed Experiment for the Riparian Scientific Advisory Group of the Forest Practices Board's Cooperative Monitoring, Evaluation, and Research Committee. T3 researchers showed examples of variable-width buffers with active management in the buffer, including thinning with gaps and thinning with red alder under planting. They also shared the first post-harvest responses of fish, in-stream wood, shade, and stream temperatures.

ONRC Rosmond Evening Talks

The Fall 2025 ONRC Rosmond Evening Talk series included a November, 2025 talk from Jill Silver, Executive Director for the 10K Years Institute. She gave a presentation on protecting watershed resiliency, improving forest health, and preventing the spread of invasive species on the Olympic Peninsula. In December 2025, DNR's Miles Micheletti presented on using drones to map forest structure to address ecological questions, and how this technique can be useful for small woodland land owners. If you missed a talk, recordings of all previous talks and lists of upcoming talks can be found **on the ONRC website**.

Summer Interns

In Summer 2025, the **Olympic Natural Resources Center (ONRC)** hosted five interns and one field technician to work on many tasks connected to the T3 Watershed Experiment. The crew prepared units for the upcoming planting season, including installation of several thousand PVC posts for the Ethnoforestry Variable-Density Planting (EVDP) prescription. This huge effort required the crew to hike up and down very steep slopes while maintaining high levels of accuracy to install plot centers at the correct locations. The crew also used flagging tape to delineate the boundaries between all sub-units in the EVDP and Cedar Alder Polyculture prescriptions.

In addition, the crew collected understory data throughout several of the units, including species cover, biodiversity, seedling count, ground cover, and biomass. These data will be used to characterize post-logging and pre-planting conditions, and can be compared to future stand conditions as the study progresses. The biomass data will also be used by University of Washington Ph.D. candidate Stacey Dixon as she pairs ground data with remotely sensed data to predict total understory biomass throughout these harvested units.

The ONRC crew gave an ONRC Rosmond Evening Talk to present their summer research. **The recording of this presentation is available at this link**.

Featured Photo

A wildlife camera in the Olympic Experimental State Forest captured this image of a bobcat mother and her two kittens. Set up in cooperation with the U.S. Geological Survey, these cameras are used to monitor the responses of large and medium-sized mammals to T3 Watershed Experiment novel prescriptions.