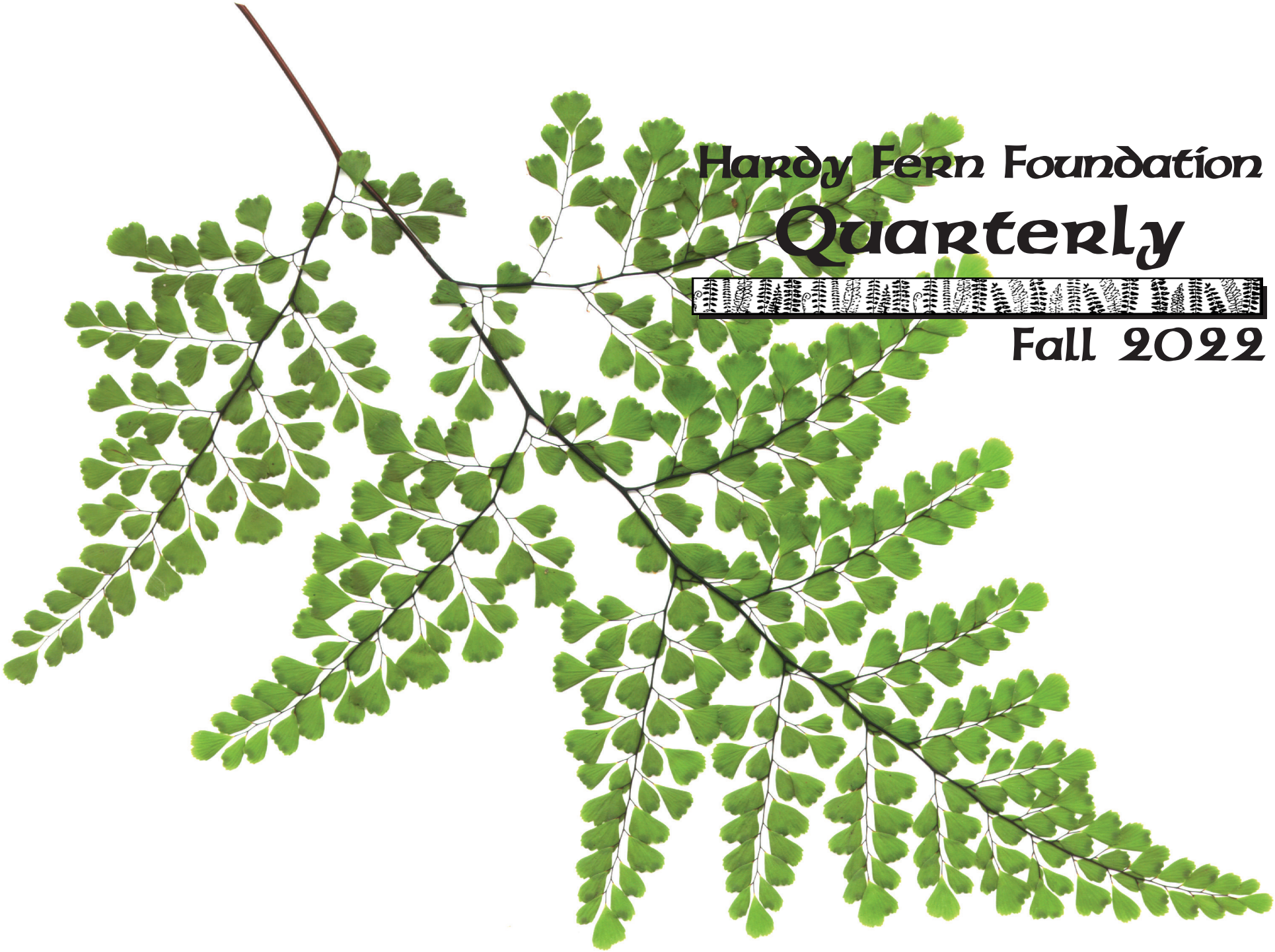

Hardy Fern Foundation Quarterly

Fall 2022

THE HARDY FERN FOUNDATION

P.O. Box 3797
Federal Way, WA 98063-3797
Web site: www.hardyferns.org

The Hardy Fern Foundation was founded in 1989 to establish a comprehensive collection of the world's hardy ferns for display, testing, evaluation, public education and introduction to the gardening and horticultural community. Many rare and unusual species, hybrids and varieties are being propagated from spores and tested in selected environments for their different degrees of hardiness and ornamental garden value.

The primary fern display and test garden is located at, and in conjunction with, The Rhododendron Species Botanical Garden at the Weyerhaeuser Corporate Headquarters, in Federal Way, Washington.

Affiliate fern gardens are at the

Bainbridge Island Library, Bainbridge Island, Washington;
Bartlett Arboretum & Gardens in Stamford, Connecticut;
Bellevue Botanical Garden, Bellevue, Washington;
Birmingham Botanical Gardens, Birmingham, Alabama;
Cornell Botanic Gardens, Ithaca, New York;
Dallas Arboretum, Dallas, Texas;
Denver Botanic Gardens, Denver, Colorado;
Dixon Gallery and Gardens, Memphis, Tennessee;
Ganna Walska Lotusland, Santa Barbara, California;
Georgia State University Perimeter College Native Plant Botanical Garden, Decatur, Georgia;
Heronswood, Kingston, Washington; ***NEW 2021!***
Inniswood Metro Gardens, Columbus, Ohio;
Lakewold, Lakewood, Washington;
Lewis Ginter Botanical Garden, Richmond, Virginia;
Powell Gardens, Kingsville, Missouri;
Rotary Gardens, Janesville, Wisconsin;
Whitehall Historic Home and Garden, Louisville, Kentucky.

Hardy Fern Foundation members participate in a spore exchange, receive a quarterly newsletter and have first access to ferns as they are ready for distribution.

Cover design by Willanna Bradner

HARDY FERN FOUNDATION QUARTERLY

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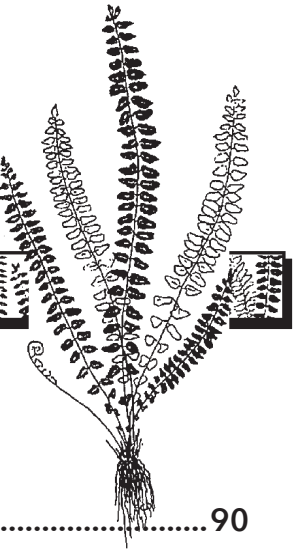


President's Message Fall 2022

HFF Quarterly – Fall Issue

At our annual meeting this fall, I will complete my term as president. Over the years that I have been serving in this position, the Hardy Fern Foundation has grown and developed considerably. We have weathered a pandemic, doubled our membership, broadened our educational outreach, expanded our affiliate garden program and restructured our fern growing to focus on spore grown ferns not regularly available in the nursery trade. Of course, this does not happen in a vacuum. I have been able to rely on an exceptional group of volunteers who serve on the board of the HFF. All of these programs, along with so much more, are accomplished through committee work and the dedication of my fellow HFF board members.

There are a few board members who I must recognize for their assistance to me during my presidency. Vice President Michelle Bundy has been invaluable to me. We have had endless hours of conversation over the years coordinating, planning and developing programs, meetings and events. She has been my sounding board for numerous ideas (both good and bad!) and has been willing to take on any task I have asked of her. Nancy Strahle, our treasurer, has been instrumental in reviewing the financial state of the HFF, helping to structure our investments and keeping us on track to a balanced budget. These duties are not glamorous to an organization but crucial to the long-term success. I would be remiss if I failed to give proper appreciation to Rick Peterson, our corresponding secretary and my husband. Rick hears all of the thoughts, ideas and plans and adds his well thought out opinion to the mix. His support and willingness to participate in the HFF with me is a joy and makes my dedication to our horticultural group just that much more fun. I am in grateful appreciation to all of those board members who chair a committee. Their dedication to the HFF and ferns makes this a fun organization for us all.

I would not be the person I am without the friendship, encouragement and wisdom of our founder, Sue Olsen. Sue along with several other founding members of the HFF made me see the beauty of ferns and sparked my desire to grow and collect these wonderful plants so many years ago. It has been a pleasure to work with her and have her advice during my presidency. Thank you, Sue, you are the best!

Finally, Dave Gibson will be retiring from the board this year. Dave joined the HFF board in 2015 actively participating in several committees. Dave has led the efforts in our auxiliary plant sales, educational programing, and along with his wife, Lori, recreated our website into what it is today. I am in grateful appreciation for all Dave has done while on our board and I am happy to say that Dave and Lori will continue to manage and maintain our website. Thanks, Dave, we will miss you and your insights at our meetings.

Thanks go to our membership for their support. The comments, correspondences and visits I have had with our members over the years have been inspiring to me. Even though I will not be president, I will remain on the HFF board, so I hope to see many of you at future events and I will be wishing you the best in your fern gardening!

All the best,

Richie Steffen
HFF President

Lovely Exotic Ferns Enhance the Northwoods

Article and Photos by Mike Heims
Hayward, Wisconsin

Trying to grow ferns from Asia, Europe, and even New Zealand in the Northwoods of Wisconsin an hour's drive south of Lake Superior and Duluth, Minnesota may seem like a daunting challenge. This region of wolves and loons is renowned for its long bitterly cold winters. A clue that it might not be as thankless an endeavor as it might at first appear comes from the incredible bounty of native fern species which grace this region. How can this be? Well, there are a couple of reasons; the first being the abundance of water in the form of lakes, streams, seeps, and atmospheric moisture. More importantly, however, is that annually an abundant crystalline precipitate of dihydrogen monoxide insulates the ferns like a down jacket from the cold, dry air of winter. This snowcover generally lasts from the end of November until late April. It also hides the evergreen ferns from predation by hungry deer.

Just as no two snowflakes are exactly alike, so it is with the many kinds of ferns. A blessing of abundant native ferns is one of the main reasons that I fell in love with my family's property. Personally contributing to this bounty even more compounds both my aesthetic and spiritual rewards. Because of its location atop a rugged kettle moraine, our property contains many microsites suited to particular ferns. These sites range from acidic woodland beneath conifers to rich hardwood forest; from *Sphagnum* bog to the stone wall surrounding our house. I do not modify the soil in any way, nor do I typically fertilize or water. I simply research what specific conditions the fern prefers to grow under and then try to match it to an existing site or sites.

A major limiting factor of course is that some fern species lack sufficient cold-hardiness, even with a snow blanket, to survive in the Northland. For some perhaps the length of our growing season is just not sufficient for them to harden off, altho I did successfully overwinter *Cyathea australis* for two years! The only other issue is occasional deer browsing of evergreen fronds in late autumn or early spring, but the ferns typically recover well from this indignity. My ferns have not experienced any obvious disease or arthropod infestations. Compared to many other plants, I find ferns easy to start and easy to grow. To start them I generally sow their spores on forest soil in baby food jars and place those beneath fluorescent lights. Usually they are transplanted twice while indoors; first into packs of forest soil and next into individual 2-inch pots. Occasionally they will need another transplanting into 4 or 5-inch pots which is a lovely reward for a little bit of effort! Plus I can enjoy them indoors over winter.

Rating key	**3. Good performance**
1. Did not survive	**4. Attractive, but not thriving**
2. Poor performance	**5. Best performance**

Ten ferns that do well in my USDA Zone 3/4 garden

Genus	Species	Rating	Comments
Adiantum	*venustum*	5	Himalayan maidenhair. Mail-order nursery stock. Can be be fussy getting established, but then spreads vigorously. Evergreen.
Asplenium	*septentrio-nale*	5	Sporelings collected in Colorado. Thriving in our south-facing rock wall in crevices of siliceous sand. Evergreen.
Athyrium	*deltoidofrons*	5	A huge, broad-spreading fern from East Asia. Grew several from spores. Thrives in swampy, acidic conifer-hardwood for-est. Herbaceous.
Blechnum	*niponicum*	5	Japanese deer fern. Grew several from spores. Thrives in swampy, acidic conifer-hardwood forest. Evergreen.
Dryopteris	*amurensis*	5	Amur wood fern. Grew many from spores. Adapted to many woodland sites. Ever-green.
Dryopteris	*chinensis*	5	Chinese wood fern. Grew many from Japanese spores. Thrives in moist, sheltered woodland. Evergreen.
Dryopteris	X *complexa*	5	Robust wood fern. Grew many from spores from commercial stock. A naturally-occur-ring fertile hybrid from Britain. Adapted to many sheltered conifer-hardwood sites. Evergreen.
Dryopteris	*crassirhizoma*	5	Have grown many from spores. Native to northeastern Asia. Beautifully symmetrical. Thrives in moist conifer-hardwood forests. Evergreen.
Dryopteris	*namegatae*	5	Namegata wood fern. My original plant came from an incidental spore in a packet of other spores from Japan. Bright green fronds. Adapts to many sheltered conifer-hardwood sites. Evergreen.
Matteuccia	*orientalis*	5	Commercial stock. Native to East Asia. A broad-growing fern resembling a short tree fern. Moist, lightly-shaded sites. Herba-ceous.

Five ferns that did not do well in my USDA Zone 3/4 garden

Aspidotis	*densa*	1	Indian's dream fern. Grew many from spores. All looked great in rocky sites until they died their first winter.
Asplenium	*adiantum-nigrum*	1	Black spleenwort. Ditto.
Blechnum	*spicant*	1	Deer fern. Collected sporelings from Olympic Peninsula, WA, western WA and OR Cascades, Germany's Erzgebirge and Schwarzwald. None survived in our creek bottom woods for more than a couple of years. They appear to overwinter fine, but dry springtime air after snowmelt kills them. Evergreen.
Dryopteris	*sieboldii*	1	Siebold's wood fern. Purchased a plant thru mail-order and grew many from spores. All looked great in both wet and drier woods until they died their first winter.
Woodwardia	*fimbriata*	1	Giant chain fern. Grew several from spores and planted them on a wooded seep. All looked great until they perished their first winter.

Five ferns that are rare or prized possessions in my USDA Zone 3/4 garden

Adiantum	*aleuticum 'Subpumilum'*	5	Grew many from spores. Fussy as to site, thriving best at the base of a basswood tree. Herbaceous.
Arachniodes	*mutica*	4	Spore-grown from Japan. Healthy, but slow-growing in open woods in our creek bottom. Evergreen.
Arachniodes	*standishii*	4	Commercial stock. Native to Korea and Japan. Doing well in deep conifer-hardwood forest near our creek. Slow-growing. Evergreen.
Asplenium	*viride*	5	Green spleenwort. A sporeling from the Austrian Alps, growing cheerily in our alpine bed. This bed does get watered. Evergreen.
Cheilanthes	*lanosa*	5	Hairy lip fern. Grown from spores. They thrive in our exposed rock wall in crevices of siliceous sand. The only species of Cheilanthes to survive here long-term. Evergreen.

Note: I was tempted to include the Southern Hemisphere's alpine water fern *Blechnum penna-marina* here, but as of yet it has not been exposed to particularly harsh winter conditions, even tho temperatures above the snow have dropped to -40.

1 Asplenium septentrionale

2 Athyrium deltoidofrons

3 Blechnum niponicum

4 Dry. amurensis

5 Dry. chinensis

6 Dry. crassirhizoma

7 Dry. nam.

9 Cheilanthes lanosa

8 Adiantum aleuticum 'Subpumilum'

Scientists Racing Against Time To Document Colombian Fern Species

Andrew Wight

Reprinted with permission from Forbes magazine
May 22, 2022

Alejandra Vasco holding a fern of the genus Elaphoglossum in Ecuador in 2018 Weston Testo

Colombian Botanist Alejandra Vasco is realizing a long-held dream to document the vast diversity of ferns in her home country, racing against time to find new species threatened by climate change and other human activities.

Vasco, a research botanist at the Fort Worth Botanic Garden and the Botanical Research Institute of Texas (FWBG|BRIT) says her current project, which included a recent collecting expedition, will improve humanity's understanding of how many fern species exist in Colombia, where they occur, and how many of them are threatened with extinction.

"We collected plants that have not been collected in 50 years, and some that are likely not described to science," she say, "We now have funding for the next four years to do this project and make this dream of studying the ferns of Colombia come true."

Colombia is the second most biodiverse country on Earth when it comes to plants, according to the Convention on Biological Diversity.

Vasco says that the four researchers who came from abroad flew together 19650 km to come to Colombia.

"In 20 days we drove more than 750 km through the Andes, making more than a thousand collections, plus duplicates, that is 4000 specimens - we will be exporting to the US for our careful study by us around 3000 collections," she says, adding that in some of the places they visited, the diversity of ferns was so high, researchers didn't have time to collect all the ferns there.

"We want to go back," Vasco says, "The project is very close to my heart, and I started thinking about it, since I decided I wanted to dedicate my life to the study of ferns."

"The biggest challenge is that the process of documenting and describing biodiversity often cannot keep up with the rate of habitat loss and the extinction of species, and this is especially true in tropical regions of the world, where the number of undescribed and poorly known species is highest, and biodiversity is most severely threatened," she says, adding that her team will now visit natural history collections in the USA and Colombia and go to places in Colombia that have not been visited much by researchers or plant collectors in the last 40 years.

"We also are teaming up with a great group of botanists and students in Colombia interested in working and learning about ferns, so I hope this project bring us all together to strengthen this group so that we can keep understanding and protecting the diversity of our great country," Vasco says.

Alejandra Vasco and team collecting ferns in the field in San Carlos, Antioquia, Colombia, 2021. Alejandro Marín

Inspired By A Teacher

Vasco was born and raised in Medellin, Colombia and says she was inspired by her biology high school teacher, a "very smart, very sweet" woman, who was also an excellent teacher.

"During a difficult time in Colombia, she had the courage of taking us (40 or so 16-year-old high school students) to see whales in the Pacific Ocean of Colombia and to the island of Gorgona," Vasco says, "That was one of my happiest experiences ever, and one of my first experiences seeing so much marine and plant diversity."

Vasco would go on to complete her undergraduate degree in biology at the University of Antioquia in Medellin before moving to the U.S. to do a PhD in botany at the joint program of the New York Botanical Garden and the City University of New York, then postdoctoral work in botany in New York, before working at the National Autonomous University of Mexico (UNAM). Since 2017 Vasco has been with the Fort Worth Botanic Garden.

Vasco says a big part of her collaborative work between the US and South America is to translate not just the language, but also the understanding of the particular idiosyncrasies of the way scientists do research and interact with colleagues in both regions.

"As a researcher who lives and works in the North but was born and raised (and has part of her heart and academic interest) in South America, I always try to facilitate interactions and conversations between both sides," Vasco says, "My hope is that my experience working in both the North and South brings what is best of us all, so that students, researchers, and the global challenges themselves all benefit from the collaborations."

Alejandra Vasco

Polypodiums on the Olympic Peninsula in Washington State

Article and Photos by Sue Olsen
Bellevue, WA

Polypodium glycyrrhiza with fall maple leaves

Fall may seem like a strange time to recommend vacationing along the Olympic coast of Washington but it is a perfect time to find *Polypodium glycyrrhiza*, the licorice fern, coating the trunks and limbs of trees especially the big leaf maple, (*Acer macrophyllum*). Why? because the fern is summer dormant and is especially lovely with fresh bright green fronds framed by the fading fall yellow leaves of the maple. (If the coast doesn't appeal to you try Bellevue Botanical Garden, Bellevue!) It is also occasionally found on red alder (*Alnus rubra*) and western white oak (*Quercus garryana*) and frequently assisted by the comfortable cushion of moss on the tree's limbs. I've also seen it happily established on mossy rocks or for that matter in the gardens of enthusiasts! Look for it along the highway as well as on inland trails and botanical gardens.

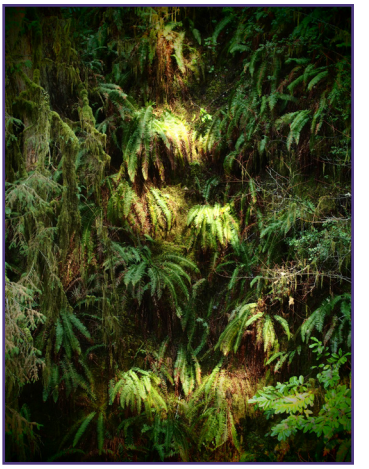
Out of curiosity I looked it up in Theodore Frye's *Ferns of the Northwest*, 1934. Here one can find all sorts of unusual information such as regarding the lady fern, *Athyrium filix-femina*, "Dioscorides taught that the leaves boiled in wine and drunk for 40 days removes infirmities of the spleen, aids in jaundice, and causes gall stones to crumble and pass away…". But I digress….. For *Polypodium glycyrrhiza* he notes, "The rhizome is strongly licorice in taste, containing the same substance, glycyrrhizin, which gives licorice its flavor. This rhizome, however, has also some bitterish substance in it". (I can vouch for that!) Elsewhere he writes that "the early settler's along Willapa Harbor used it to flavor tobacco…..and when made into a decoction and taken internally is good for melancholia and troublesome dreams or finally fresh rhizomes crushed or dry rhizomes powdered, mixed with honey and applied to a member that is out of joint

'doth much help it'" Soooooo, enjoy it and plant it in the ground in your shade garden where it is great for winter interest. It grows to a foot or more, creeps slowly but is not invasive. Zones 5-8.

Polypodium glycyrrhiza

Meanwhile there are several cultivars which are very rare in the wild but are highly garden worthy. My favorites are *Polypodium glycyrrhiza* 'Malahatense' which is a usually sterile fringed form (originally found on the scenic Malahat Dr. in Victoria, BC). It makes a lovely carpeting ground cover and shares space nicely with ornamental summer substitutes which fill in while the fern enjoys its dormant period. Add *Polypodium glycyrrhiza* 'Longicaudatum' which has flat tongue like small overlapping fronds and is a choice option that will snuggle along in the shady section of a rock garden.

Polpodium glycyrrhiza 'Malahatense



Polystichum munitum Quinault

The other must see polypodium is *Polypodium scouleri* (check the imaginatively named beaches 1 and 4). Again, it is a tree dweller this time with a preference for old or dead spruce trees (*Picea sitchensis*……While there look for the world's largest at

Lake Quinault.) The fronds are leathery, sturdy and very shiny and clump in or near the tree's crotches (or when available burls) and in time slowly crawl. (Visually they could pass for poorly constructed bird's nests!) It is site choosy however and in nature only grows within a few hundred yards of the salty Pacific Ocean from British Columbia southward. It was discovered in 1825 at the mouth of the Columbia River by Dr. John Scouler a companion of David Douglas (think Douglas fir!) Like the licorice fern it readily adapts to cultivation this time with a preference for acidic soil in a completely shady habitat (and you don't need dead spruce trees). Be patient and it will spread slowly and unlike the deciduous licorice fern its foot tall fronds are a welcome evergreen. Zone 8-9.

Polypodium scouleri Beach 4

(In a hurry? You can find both of these species at the South Beach Campground among many other options but please don't make this your only stop!!)

Tree with Polypodium glycyrrhiza at South Beach
photo by Greg Olsen

Now while you're in the area be sure to visit Lake Quinault where there are numerous trails including an excellent nature trail starting on the South Fork Road. You can take the short route or a longer one (say two miles or so which if you time it right will get you to the Quinault Lodge in time for a nice lakeview lunch). You'll be surrounded as everywhere along the way by our outstanding natives especially the deer fern, *Blechnum spicant* (look carefully and you might find gametophytes) and the ever-present sword fern, *Polystichum munitum*. However, the area's prize is *Adiantum aleuticum,* our western maidenhair which drapes on banks during its summer glory.

And yes, there's more so I'll conclude with a recommendation for the Hoh Rain Forest. This is a bit of a drive inland (get there early) and is truly a magnificent temperate rain forest immersed in lush foliage (including the *Polypodium glycyrrhiza*). The highlight however is the *Selaginella oregana* hanging everywhere and referred to by most visitors as moss!!!

Whoops, don't forget to stop at the beaches!!! And near the Kalaloch campground you can find The Tree of Life! 🙂

Blechnum spicant is also classified as Struthiopteris spicant.

Welcome New Members

Russ Bogue
Ananda Dorje
Darlene Granberg
Michael Hagen New York Botanical Garden
Tere Kaulfus
Nancy Miller
Richard and MaryAnn Moore
Kevin Tepas
Carol Tinker
Shawna Van Nimwegen
Norma Vandenberghe
Alejandra Vasco Botanical Research Institute of Texas

The Unfurling Blight

Article and Photos by Dylan Mendenhall
Bremerton, Washington
September 22, 2022

Reprinted with permission from Douglasia magazine Volume 46 Number 2.

It felt like we were exploring another planet, not conducting a field study in our own backyard of the Pacific Northwest. The understory twilight of the old growth forest was hazy with the smoke of our world burning up, and our voices were muffled by N95s, as much for the wildfires as for the pandemic.

After scrambling up a ladder of roots, our field crew reached a plateau in the heart of the forest, one of the few remaining patches of old growth in the Puget Sound lowlands. Having conducted research in those woods several years prior, I knew that there were plants in that area that were nowhere else for miles around, species such as star-flowered false Solomon's seal (*Maianthemum stellatum*), spreading gooseberry (*Ribes divaricatum*), sweet-scented bedstraw (*Galium triflorum*), and mock orange (*Philadelphus lewisii*). Common enough, regionally perhaps, but to me, it was a blessed place, made all the more immersive by the matrix of sword ferns (*Polystichum munitum*) adorning every surface. For the purposes of our study, it was isolated. And it was old. The perfect place for a control group.

At the end of the day, we sterilized our boots and threw away the surgical gloves that we used for collecting tissue samples. Finally, I cleansed my hands with ethanol.

You could never be too careful. Preliminary research suggested that the pathogen was transmissible. Was it airborne? Was it in the soil? Was it transmitted by an insect? Our meticulous protocols verged on paranoia, but it wasn't for our own safety that we took such precautions.

Unlike COVID-19, this disease only kills sword ferns.

Tip die-back on a symptomatic sword fern.

Anatomy of a blight

Signs and symptoms

Sword ferns are withering away at dozens of locations across the Pacific Northwest (Shannon 2020a), including some especially cherished places such as Islandwood, Seward Park, Tiger Mountain and Kanaskat-Palmer State Park. Most of these declining sword fern populations are clustered around Puget Sound, but they have also been reported in western Oregon.

The sword fern blight is associated with a suite of symptoms that closely resemble the effects of drought stress. Contributing to the ambiguity, the specific set of symptoms and their degree of severity vary from individual to individual. Based on my personal experience, the visual symptoms include any combination of crispate pinnae, a contorted rachis, discoloration, aborted frond development and tip die-back (Mendenhall and Barrera 2021). Sometimes the ferns have a scorched appearance, like kale chips left in the oven for too long. Other times, it looks as though the fiddleheads stopped unfurling halfway through the process. Most of the time, the fronds look "crinkly".

Although sudden mortality events have certainly been observed, the blight is also associated with a slower and more subtle demise, marked by a gradual decrease in frond production over time. Normally, a healthy sword fern can retain its fronds for multiple years, having as many as three distinct sets of fronds at any given time, with each set having a similar number of fronds. In contrast, symptomatic ferns tend to have a lower ratio of young fronds to old fronds, resulting in them looking increasingly shabby and sparse. Once their fronds have withered away completely, most ferns do not recover.

To put it simply, the ferns look… bad. They look really bad. And the badness is contagious.

Crispate pinnae on a symptomatic sword fern.

An invisible wave

What could be responsible for such destruction? Previous research has explored a wide range of hypotheses, including studies on soil compaction, nutrient limitations, herbivory by mountain beavers, and known plant pathogens such as *Phytophthora* (Kildisheva and Aghai 2018). One of the more prominent conjectures has been that drought stress is to blame, an intuitive explanation given that most of the symptoms look, well, exactly like drought stress. Beyond those visual similarities with drought, however, little evidence has actually been put forward to support the hypothesis.

Anecdotal observations conflict with this idea. For example, we might expect abiotic site conditions, such as water availability, to affect other plants in the vicinity. Yet the sword fern blight appears to leave co-occurring species unaffected. Dwarf Oregon grape (*Mahonia nervosa*), osoberry (*Oemleria cerasiformis*), elderberry (*Sambucus racemosa*), fringecup (*Tellima grandiflora*), and red huckleberry (*Vaccinium parvifolium*) are all examples of native species that persist in the wake of the blight.

Furthermore, sword ferns are among our more drought tolerant species, capable of fully recovering after periods of severe drought (Baer et al. 2016). It seems unlikely that sword ferns would perish from drought stress when their more sensitive companions remain unscathed.

Another problem with the drought hypothesis is that it doesn't explain the apparent transmission of the disease. In Seward Park, where an initial die-off was first observed in 2013, the blight continues to move through the forest like an invisible wave, spreading outwards year upon year. I am unaware of an abiotic process that could facilitate such travel.

Recent findings

Transmission

Our first major breakthrough happened during a greenhouse experiment at the Center for Urban Horticulture, through a collaboration with Marianne Elliot, a plant pathologist at Washington State University, and Paul Shannon, a senior software engineer at the Institute for Systems Biology. Under the assumption that the blight was caused by a pathogen, we hypothesized that exposure to diseased tissue would cause healthy ferns to develop symptoms similar to those observed in the field.

We tested that hypothesis by placing fronds from healthy ferns in containers of water shared with either diseased tissue or healthy tissue. After 12 days of exposure, the fronds exposed to the diseased tissue had almost completely withered away, resulting in significantly lower foliar moisture content compared to the fronds in the control group (Mendenhall et al. 2019). Personally, I found the speed and severity of the effects to be, quite frankly, horrifying.

These findings were soon followed up by an elegant field study in which Paul Shannon planted healthy nursery-grown ferns in what appeared to be the path of

the blight (Shannon 2020). Eventually, the invisible wave overtook the young ferns. After two years of exposure, they had significantly fewer fronds compared to the ferns planted nearby in a control group.

We had confirmed our suspicion. The blight was transmissible.

Chlorophyll fluorescence

Despite having strong evidence for transmission, the diversity of symptoms was endlessly vexing. How could we even define the phenomenon if we couldn't describe a single consistent symptom? I also wondered if the old shabby look of the ferns might be the result of them simply being old shabby ferns. It was the parsimonious explanation. To answer these questions, I turned to a commonly used metric for evaluating plant stress: chlorophyll fluorescence.

Of the many quirks involved with photosynthesis, my favorite is the capacity of chlorophyll molecules to shed their excess energy by re-emitting photons of light, a process called fluorescence. One way to measure chlorophyll fluorescence is to compare the variable fluorescence (F_v) with maximum fluorescence (F_m). In healthy plants of almost any species, the dark-adapted F_v/F_m values generally hover around 0.8 or higher, while lower values are often interpreted as an indicator of plant stress (Maxwell and Johnson 2000).

To my surprise, I found that among healthy sword ferns, the young fronds and old fronds both have F_v/F_m values around 0.8, which suggests that older fronds are able to efficiently photosynthesize well into their second or third year. In contrast, the chlorophyll fluorescence values of symptomatic ferns were significantly lower, with F_v/F_m values as low as 0.45.

Results from a transmission experiment, comparing a frond exposed to healthy tissue (left) with a frond exposed to diseased tissue (right).

In the world of plant physiology, numbers like that mean pain. To put it more objectively, these results suggest that symptomatic ferns are indeed under considerable stress, and the physiological changes associated with the blight are distinct from the normal aging process that fronds go through from year to year. Something else is at work besides time.

Mother trees and nurse logs

At the die-off site in Seward Park, Paul Shannon noticed a pattern. The handful of ferns that survived appeared to be located near trees and logs. Could big trees and decaying wood provide some form of protection to the ferns?

To explore this question, Paul and I conducted a study in which we carefully mapped the locations of over 200 ferns and used vector algebra to determine their distances to the nearest trees and logs. We found a weak but statistically significant relationship between their likelihood of survival and their proximity to trees and coarse woody debris (Shannon 2019). There also appeared to be thresholds for the minimum and maximum distances associated with greater survival. For example, none of the sword ferns survived if they were more than 15 ft from a tree or log.

The mechanisms that could give rise to this pattern are unclear to me. If I was to wildly speculate, however, I imagine that the trees and logs may relieve some sort of compounding stress that the sword ferns experience, perhaps by increasing soil moisture in their vicinity through the hydraulic redistribution of water stored deeper underground. In the case of logs, I imagine there could be a similar effect from the passive release of water from their decaying wood. If the sword fern blight is primarily driven by a pathogen, it almost certainly interacts with the seasonal drought conditions of the Pacific Northwest.

Social distancing

When people are crowded together in a room, it's easier for an airborne pathogen to be transmitted from person to person. A similar pattern occurs with plants in a phenomenon known as density-dependent mortality. Higher densities of a host species increase the chances that a pathogen will spread from neighbor to neighbor, for example, through root grafts, branch wounds or insect vectors. If a pathogen was responsible for the sword fern blight, I expected to see a similar density-dependent pattern.

After comparing estimates of historical fern densities with our current observations in Seward Park, I found the mortality rates to be significantly correlated with the historical densities. Based on a linear regression model, areas with nearly continuous sword fern cover are predicted to have over 90% mortality. In contrast, areas with only 20% sword fern cover are predicted to have a mortality rate closer to 50%. If this pattern holds true for other areas affected by the blight, I fear that sword ferns will decline until they become a minor component of these plant communities.

Our study

In 2020, I participated in a research project through a collaboration between Friends of Seward Park, MPG Ranch, and my business, Haven Ecology and Research LLC. After collecting tissue samples, soil samples and observations on the site conditions at Seward Park, we explored two competing hypotheses. Is it drought stress or a pathogen?

Mediterranean summers

In the Pacific Northwest, we are blessed with a so-called Mediterranean climate, characterized by mild winters and parched summers. If the sword fern die-off was caused by drought conditions, perhaps exacerbated by climate change, one might expect the symptoms to be especially pronounced during our yearly summer drought season. One might also expect the blight-stricken ferns to have more severe symptoms in areas where the soil tends to be drier.

During the late summer, we compared the foliar moisture content and soil moisture content at sites containing predominantly healthy ferns or symptomatic ferns. Similar to our greenhouse results, we found symptomatic ferns to have significantly lower foliar moisture content compared with healthy ferns (Mendenhall and Barrera 2021). In itself, that finding was consistent with what we might expect from drought stress. The soil moisture content, however, was similar between these two groups. There was

Discolored fronds on a symptomatic sword fern.

no correlation – the symptomatic ferns were drying up, but it was not for lack of water.

Next generation sequencing

To explore the pathogen hypothesis, we focused on the fungal kingdom as a likely taxonomic hiding place. After extracting DNA from the rhizomes of both symptomatic ferns and healthy ferns, we sequenced the fungal DNA using a technique called metabarcoding. The challenge was in sorting through millions of DNA sequences, looking for something that may not even be there. Towards that end, I applied a permutational method called indicator species analysis, which essentially determines how well each DNA sequence correlates with the experimental groups – symptomatic ferns or healthy ferns. If a fungal pathogen was present, this powerful statistical test should find it.

However, instead of finding a pathogen in the symptomatic ferns, the algorithm identified a single sequence that was significantly correlated with healthy sword ferns, but largely absent in the symptomatic ferns. If this was a smoking gun, it was pointed in the wrong direction.

Based on similarities to known fungal species, the DNA sequence was identified as an unclassified species in *Cronartiaceae*, a family of pathogenic rust fungi. Readers with a background in plant pathology will recognize this as the same family that contains *Cronartium ribicola*, also known as white pine blister rust.

In any case, what was a rust doing in the rhizomes of healthy sword ferns, and why was it missing in the symptomatic ferns? I suspect that under normal circumstances, sword ferns are one of the alternate hosts for this pathogen, which perhaps infects other plant species during the other parts of its life cycle, much like white pine blister rust. It is difficult to explain why the pathogen would be missing in symptomatic ferns though. When plants are under stress, they tend to be more susceptible to pathogens, not less so.

If I was to wildly speculate once again, I imagine that the pathogen responsible for the sword fern blight somehow alters the conditions within its host to such an extreme that it becomes an inhospitable place for the other microbial denizens. It outcompetes the other plagues.

Next Steps

An ecological cornerstone

Sword ferns play a multifaceted role in the forests of the Pacific Northwest. They provide dense understory cover for ground-nesting birds, and winter forage for deer and other herbivores. During rainstorms, their evergreen leaves and wiry roots are extremely effective at preventing soil erosion and stabilizing the banks of salmon-bearing streams. As the sword fern blight continues to spread through the Puget Sound lowlands, it threatens to degrade the ecological functioning of these forests. Further research is needed to identify the mechanisms that are driving it.

Applications and future research

Although we have yet to identify the pathogen responsible for the sword fern blight, our existing knowledge of the phenomenon has applications for natural resource management. Based on the results of the proximity study, for example, we now have a sense of the minimum and maximum distances to trees or coarse woody debris that are associated with greater survival rates. By extension, land managers can modify the densities of trees or coarse woody debris to facilitate greater survival, or prioritize the planting of sword ferns within those proximity thresholds where they are more likely to survive. The density-dependent mortality pattern is another useful finding, allowing us to estimate the total area of groundcover that will eventually be lost in areas affected by the blight. For the restoration of these areas, this pattern can also be used to predict the sword fern planting densities that will encourage greater survival.

A SUDDEN MORTALITY EVENT IN A STAND OF SWORD FERNS.

Future research should build on our progress by using DNA sequencing to target other sword fern tissues, such as the roots or foliage, or by focusing on other taxonomic groups known to harbor plant pathogens, such as bacteria or oomycetes. There is also a need to better understand how the pathogen is transmitted. Our greenhouse study suggests that the causal agent is at least capable of being transmitted through water. However, in the natural environment, it is plausible that an insect or some other vector facilitates its transmission.

Lastly, research is needed to evaluate the susceptibility of other *Polystichum* species that are native to the Pacific Northwest, such as *P. andersonii*, *P. californicum* or *P. imbricans*. If not for the purpose of their own conservation, such research could potentially identify a resistant species that could be used for habitat restoration. It may be the twilight of *Polystichum munitum* at some locations in Washington, but there is hope that we can restore the structure of these forests, normally awash by a perennial sea of fronds.

How to get involved

One way that folks can contribute to the research is by reporting suspected sword fern die-offs through the iNaturalist project, *Western Sword Fern Decline in the Pacific Northwest*, managed by Paul Shannon. This community-based monitoring effort helps us better understand the geospatial extent of the phenomenon and provides researchers with potential locations for future experiments. As good stewards of the earth, I also plead that we avoid moving soil, plants or woody debris from areas affected by the blight, and that we wash our boots after travelling to such places. Lastly, readers can advocate for greater participation from state and federal land managers. Most of the research mentioned here was funded by a small group of thoughtful committed citizens, devoted to the celebration, preservation and restoration of Seward Park.

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Ferns of the Olympic Peninsula

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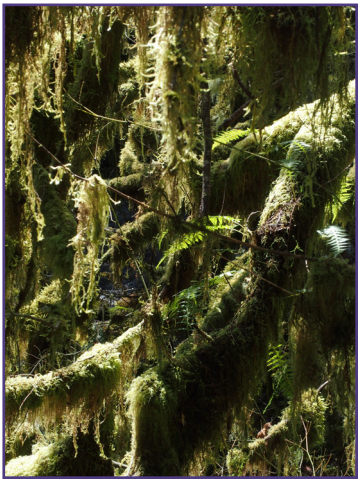

Hoh Rain Forest

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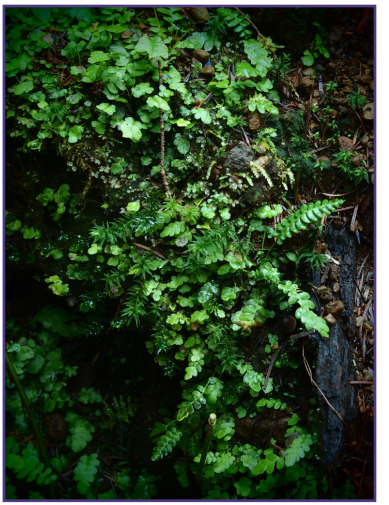
Hoh Rain Forest

Blechnum spicant



Blechnum spicant with gametophytes

Happy Autumn

The Living Tree near Kalaloch

Polystichum munitum

Thank you Richie!

HFF President

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