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PERMAFROST PATHWAYS

Woodwell launches new project monitoring, combatting the effects of permafrost thaw

A \$41 Million grant through The Audacious Project will fund Permafrost Pathways work

Sarah Ruiz Science Writer



It's a big idea—a pan-Arctic monitoring network for permafrost emissions—but big ideas are exactly what The Audacious Project was created to foster.

This April, Woodwell Climate Research Center was awarded 41.2 million dollars through Audacious to not only build such a network, filling gaps in our understanding of how much carbon is released into the atmosphere from thawing permafrost, but also to put research to work shaping policy and helping people.

The new project, called Permafrost Pathways, combines scientific prowess from Woodwell with policy, community engagement, and Indigenous knowledge from the Arctic Initiative at Harvard Kennedy School's Belfer Center for Science and International Affairs, the Alaska Institute for Justice (AIJ), and the Alaska Native Science Commission.

Carbon emissions from permafrost thaw are one of the biggest areas of uncertainty in global climate calculations. Thawing permafrost is expected to release between 30 and 150 billion tons of carbon by 2100, the higher estimates on par with or even exceeding the United States' cumulative emissions if allowed to continue at current rates. Yet permafrost is not accounted for in carbon budgets and international agreements. Permafrost Pathways will develop more complete data on permafrost carbon and deliver that research into the hands of those poised to decide how we deal with the warming Arctic.

Big problems require big solutions

Permafrost Pathways is led on the Woodwell side by Arctic Program Director Dr. Sue Natali and Associate Scientist Dr. Brendan Rogers, who have both been researching permafrost carbon for years. Dr. Natali found her way to the Arctic through a desire to work in a place significant to the global carbon story. The rapid changes she has witnessed in the past decade have underscored the Arctic as ground zero for climate change.

"I've seen dramatic changes from one year to the next in the places where I work, and Arctic residents have been observing these changes for decades," Dr. Natali says. "You can measure something one year and then the ground there collapses the next. The physical changes across the landscape are really startling to see."

Drs. Natali and Rogers have seen eroded hillslopes, research trips abandoned due to wildfire, community meetings with Arctic residents whose homes are sinking—every experience reinforced the fact that there was still much more to learn about how thawing permafrost feeds into climate change and is impacting Arctic communities.

The Audacious grant will allow Drs. Natali and Rogers to pull together the threads of their prior research into a project that starts to tackle the issue on a grander scale.

"When you're focused on individual problems or hypotheses, you're not able to really think big about something like monitoring across the Arctic," says Dr. Rogers. "Opening up a funding source like this lets you think at a scale that matches the problems we face."

The project is thinking really big, with the goal of installing 10 new eddy covariance towers—structures with instruments that measure carbon flux—in key areas where data is currently lacking. Pathways will also maintain existing key towers that would otherwise be decommissioned, and augment others to measure carbon fluxes year-round.

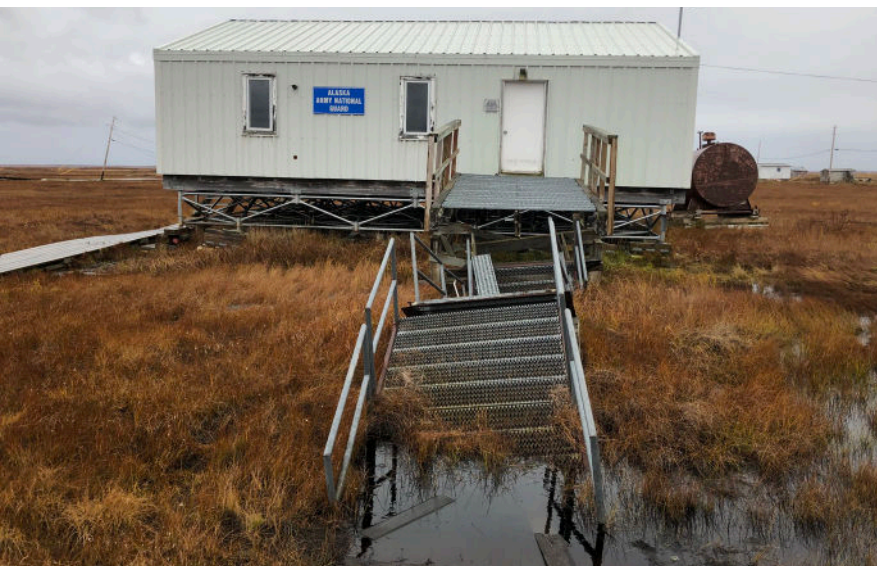
"There are a lot of existing towers that are either not running through the winter, or they're not measuring methane, or they're on hold for instrumentation upgrades or lack of funding," Dr. Natali says. "We will get even more new data by maintaining old towers than constructing new ones."

In parallel, Woodwell will work with a team at University of Alaska Fairbanks to develop a novel permafrost model that fully harnesses the data, accounting for important but currently neglected processes, and ultimately delivers more accurate projections of permafrost emissions to inform policy makers and Arctic communities.

'It's an awful decision'

While the science team ramps up new data collection, AIJ will be breaking down the issue of adaptation. The Arctic is warming faster than anywhere else on Earth, and it is not waiting for exact measurements to make the consequences known.

The land upon which many Alaska Native communities are located is destabilizing in the face of *usteq*—a Yupik word for the catastrophic ground collapse that occurs when thawing permafrost, erosion, and flooding combine to pull the ground out from under them. In many places the formerly solid cornerstones of villages—houses, roads, airports, cemeteries—have had to be picked up and moved to more stable ground.



"It is an awful, awful decision that communities are being faced with because the land on which they're living is becoming uninhabitable," says Executive Director of AIJ, Dr. Robin Bronen.

On top of the trauma of watching their villages sink into the Earth, there is no clear path for Arctic communities deciding they must completely relocate.

"It's become painfully clear that we in the United States have no institutional or governance structure to facilitate this type of movement of people," says Dr. Bronen. There is no standardized way for people displaced by the climate crisis seeking resettlement to apply for funding and technical assistance for a community-wide relocation.

"If policy changes aren't made nationally, then a lot of communities in the United States are going to be experiencing

this incredible disconnect between making the decision that they are ready to leave, but having no resources to implement that decision," says Dr. Bronen.

Permafrost Pathways will be working with Arctic residents to help them adapt to their rapidly shifting landscape. Through AIJ and the Alaska Native Science Commission, the project will connect with communities, collaborate to generate data they can use in their decision making and, if they make the choice to move, work with them to secure the resources needed for relocation.

Factoring permafrost thaw into our global future

Permafrost Pathways isn't the first to tackle these issues but, Dr. Natali says, it does represent a unique combination of expertise that could push forward both carbon mitigation and climate adaptation policies.

Leader of the Arctic Initiative, professor, and Senior Advisor to Woodwell's president, Dr. John Holdren understands the value of connections in making lasting change; he has been speaking to top policy makers in the U.S. and abroad for much of his career.

"All of us at the Belfer Center have been linking science and policy for a long time and communication is important to that," says Dr. Holdren. "In my view, it's going to remain important to have personal connections at high levels."

Working through these connections, Permafrost Pathways will put the project's science into the hands of policymakers to impress upon them the issue's urgency.

"All the news coming out about permafrost carbon has been bad news," says Dr. Holdren. "I think what we are going to find is that the high estimates are much more likely to be right than the low estimates. We've got to get that factored into the policy process."

For Dr. Natali, the most important outcome of Permafrost Pathways is a future in which the threats presented by permafrost thaw are taken seriously by governments.

"I want to see permafrost thaw emissions accounted for," says Dr. Natali. "I want to see the national and international community actually wrestle with the effects of permafrost thaw and to take action to respond to the climate hazards."

Dr. Rogers says he hopes the collaborative nature of this already-big project will have even larger, rippling effects—paving the way for new partnerships and policy change.

"There's the critical work that we will be doing, and then there are the new doors that a project of this scope opens," says Dr. Rogers. "And we aren't reaching our end goal without those open doors."

Are Alaska's streams getting too hot for salmon?

A brutal summer spurs new research on heat stress in Chinook salmon

Sarah Ruiz Science Writer



Madeline Lee's first year on the Ninilchik River was the year the salmon went belly up.

Lee had just joined the Alaska Department of Fish and Game, helping count fish on their way up the river. It was her first time ever working with salmon, but even so, she could tell something wasn't right with them.

"Their behavior seemed strange to me," she recalls—they swam lethargically, rather than surging upstream. Veteran Fish and Game techs agreed and hypothesized it was the warmer-than-usual weather.

Then reports started coming in from other rivers. Across the state that summer, locals were reporting dead salmon in the water, stranded on the gravel shallows, and washed up on the banks.

A team of scientists working on the Koyukuk River tallied 850 dead in that system alone. The true total was likely greater, as fish corpses normally sink and decompose out of view. But the real cause for alarm was the fact that, when the fish were cut open and examined, they were full of eggs. Their several-hundred mile return journey to their birth rivers ended just short of the finish line, without depositing the eggs that would grow a new generation. Across the state of

Alaska, more than 100 different places saw early salmon mortality during the summer of 2019.

2019 broke Alaska's all-time temperature records

"Warmer-than-usual" may be an understatement. 2019 broke Alaska's temperature records with an all time high of 90 degrees Fahrenheit—resulting in nearly 80 degree stream temperatures. Most Pacific salmon species reach an acceptable temperature threshold between 60 and 70 degrees. Above that they become stressed, behave abnormally, and eventually die.

Sue Mauger is Science & Executive Director of Cook Inletkeeper, an NGO that protects the Cook Inlet watershed, which includes the Ninilchik River. She is also a part of an interdisciplinary project led by Woodwell Climate Associate Scientist Dr. Anna Liljedahl that will gather data on salmon for use in policy decisions on the Kenai Peninsula. Mauger has made her career out of studying water temperatures in Alaska's streams. In 2002, she dropped her first temperature logger into a stream out of curiosity. The results—70 degrees Fahrenheit—were surprising even then.

Since then, she's been wading through rivers, compiling data on how water temperatures have been changing. From 2002 onward, "we've had more warmer summers than not," Mauger said. "And then we hit 2019, which is one we will probably talk about for most of our careers now."

Mauger had previously conducted a five year temperature study on Cook Inlet salmon streams and used the data to predict water temperatures 50 years into the future. Temperatures in 2019 exceeded them.

"We suddenly jumped so far ahead into the future compared to what we thought we would see," Mauger said. And the consequences of that jump were made clear when salmon started dying with their eggs still inside them.

Salmon and people have a 12,000-year-old relationship in Alaska

Alaska and salmon are more than interconnected—they are synonymous. So if salmon runs are in jeopardy, many Alaskans believe Alaska is too.

Salmon start their lives as minuscule hatchlings, sheltering and feeding in the gravel beds of small streams before moving downstream to larger habitats as they grow. Once they're large enough to hold their own, they leave their birth streams for the open ocean.

After a few years at sea, adult salmon return home to the precise streams where they were born. Navigating using the Earth's magnetic field and a strong sense of smell, salmon surge up streams en masse in the summer, climbing waterfalls, avoiding hungry bears, eagles, and humans, fighting for the chance to mate and lay their eggs in the gravel shallows.

Salmon's return migration has been foundational to Alaska Native cultures for 11,800 years. Indigenous peoples

MORE

View the multimedia story at:
woodwellclimate.org/too-hot-for-salmon



continue to steward the resource to maintain healthy populations in their home streams. For tribes, salmon is part of their individual and cultural identities—both a sacred fish and a subsistence food source. Salmon hauled in during the summer are smoked and dried to sustain communities through the winter.

Alaska's economy also revolves around salmon. The seafood industry created \$5.6 billion in economic activity for the state in 2017 and 2018, and salmon comprised the majority of that value. From commercial fisheries, to sportfishing, to salmon tourism, Alaskan businesses depend on the salmon completing their life cycle each year, which is why the egg-carrying corpses of 2019 had such a rippling impact across the state. If you hadn't been paying close attention to salmon before, you were now.

'Chaperone' protein acts as a hidden signal of heat stress

Dr. Vanessa von Biela had been paying close attention to the salmon. As a research fish biologist at the United States Geological Survey's Alaska Science Center, she was working on a paper about heat stress signals in salmon when the 2019 heat wave hit and made her research more pressing.

"It was a weird mix of emotions. I was scared to see change that fast but also it was a relief that somebody other than me was going to know that it was a problem," Dr. von Biela said.

It also raised a lot more questions—is there a sharp temperature threshold

after which heat stress overtakes salmon, or is it a gradual decline? How resilient is the system to high temperature years? What would a warmer future look like for salmon?

Lee is now earning her master's degree at the University of Alaska, Fairbanks with guidance from Dr. von Biela, hoping to answer some of those questions. Her research is part of Woodwell's salmon project. For the past two summers, Lee has been tagging salmon and taking tissue samples to create a reference for how the fish are responding to changing temperatures.

She's doing this by searching for a specific protein in the tissue of the fish, colloquially called "the chaperone" but scientifically referred to as Heat Shock Protein 70. When salmon get too warm, parts of their cells fall apart, breaking down normal functions. The chaperone binds to parts of the cell to keep them together and functioning.

It's meant to carry the salmon through warm days until they can get to cooler waters, but it's not a permanent adaptation.

"If you're hot and you turn on a fan, it can make a difference for a while. It can be the difference between you being comfortable and you being uncomfortable," Dr. von Biela said. "But at some point, it doesn't matter how high the fan is going, you're just hot. And all of a sudden you're uncomfortable again."

At some point, the energy required to produce the emergency protein,

combined with their body's high demand for oxygen in warmer water, simply overwhelms the fish's energy reserves. Add to that the fact that spawning salmon are already pushed to their physical limits during migration. They stop eating and dedicate all their remaining energy to pushing their way upstream and developing eggs. The rising heat hits them at the worst possible time.

Keeping Alaska's waters cold

Salmon's continued success in Alaska hinges on the ability to keep streams cool, even as the climate warms. And managing stream temperature relies on managing the land around it.

Streams and rivers in Alaska can get their water in one of three ways—fed by rain and snow, groundwater, or melting glaciers. Rainfed streams tend to be warmer, fluctuating with daily air temperatures. Glacial streams actually get colder on hotter days as more ice from the melting glacier gets flushed downstream, though over time, this diminishes the glacial ice available to cool downstream reaches.

Groundwater-fed streams, however, take on the average annual air temperature of a region. On both warm and cold days, the water temperature remains consistent. Mauger has been working with thermal imagery to track down groundwater sources that feed salmon streams on the Kenai Peninsula. Protecting them could give spawning salmon a needed boost.

above, left: Salmon / photo courtesy of Alaska Department of Fish and Game

above, center: Measuring salmon at a mobile stream station, 2021 / photo by Madeline Lee

above, right: Associate Scientist Dr. Anna Liljedahl holds an example of a salmon carcass still containing eggs, 2020 / photo by Madeline Lee

“Think of them as little cold water faucets along the stream channels. Those places will become increasingly important as an adult salmon comes back up the stream. It can use these cold water stepping stones to get its way up to the spawning beds,” Mauger said.

These faucets can be anywhere—crossing state, federal, tribal, and private land, which makes protecting them a complicated task. It’s a problem that conservationists run into at every stage of the salmon’s life cycle, notes Kenai Peninsula Borough’s Land Manager, Marcus Mueller. From the spawning beds to the ocean and back again, salmon unwittingly cross human-drawn boundaries.

“There’s a lot of human influence on the salmon journey which becomes important when you want to see that cycle complete and turn around again and continue,” Mueller said.

‘Salmon have a people problem’

Mueller is thinking about how to incorporate the data from the project into land management decisions. Cook Inletkeeper has already piloted a successful protection program for lands with groundwater sources—working with the Kachemak Heritage Land Trust to send information to landowners about the value of their land for salmon and offering to buy it in trust. Another proposed management strategy is maintaining riparian vegetation along stream banks to provide shade during the extended days of the Alaskan summer.

But these solutions are not simple to implement. The Kenai Peninsula is a county-level municipality the size of West Virginia, and the people who live in it have diverse, sometimes conflicting perspectives on Alaskan natural resources. Though the state tends towards limited government intervention, Mueller notes there have been past examples of compromise for conservation. With something as culturally important as salmon on the line, he says, people will

find a way to come together to solve the problem.

“Salmon have a people problem,” Mueller said. “And the only way we can figure it out is through conversation. My hope for what comes out of this project is that we move the conversation forward.”

Lee has been working to engage the Ninilchik tribe with her project, to help center their voice in the ensuing conversations. On both the Ninilchik and other rivers, Alaska Native tribes have suffered restrictions of their rights to fish because of crashing salmon fisheries, an outcome of excluding tribal input in policy decisions.

“There’s a history of extraction of knowledge that we don’t want to be a part of,” Lee said. “If we are going to progress in this project we need the tribe on board.”

Her research required access to tribal land, so she has made sure to update tribal leadership on the science, inviting members of the Ninilchik Native Association to project planning meetings and presenting her findings to their council. She also hired a Ninilchik youth intern to help collect samples in the summer of 2021.

Dr. Liljedahl hopes to grow the project through new grants, to continue building relationships in the region and gathering more data on the pressure climate change is placing on wild salmon. In the end though, the fate of Alaskan salmon will come down to the willingness of Alaskan people to work through hard conversations—first about land and fisheries management, but eventually, inevitably, about global scale responses to climate change. Because the temperature is going to keep rising, and every degree will make a difference.

The Salmon and People project is a multi-year research project into the impacts of climate on salmon and salmon culture in Alaska. It was funded by the Fund For Climate Solutions, an internal granting program that provides resources to cutting-edge projects to get big ideas off the ground.

Unchecked boreal fires are eating into our carbon budget

Proper management could be a cost-effective solution

Sarah Ruiz Science Writer

What’s new?

A recent paper, published in *Science Advances*, has found that fires in North American boreal forests have the potential to send 3 percent of the remaining carbon budget up in smoke. The study, led by Dr. Carly Phillips, a fellow with the Union of Concerned Scientists (UCS) in collaboration with the Woodwell Climate Research Center, Tufts University, the University of California in Los Angeles, and Hamilton College, found that burned area in U.S. and Canadian boreal forests is expected to increase as much as 169 and 150 percent respectively—releasing the equivalent annual emissions of 2.6 billion cars unless fires can be managed. The study found proper fire management offers a cost-effective option, sometimes cheaper than existing options, for carbon mitigation.

Understanding boreal forest carbon

Boreal forests are incredibly carbon rich. They contain roughly two-thirds of global forest carbon and provide insulation that keeps permafrost soils cool. Burned areas are more susceptible to permafrost thaw which could in turn release even more carbon into the atmosphere. Although fires are a natural part of the boreal

ecosystem, climate change is increasing the frequency and intensity of them, which threatens to overwhelm the forest's natural adaptations.

Despite the value of boreal forests for carbon mitigation, the U.S. and Canada spend limited amounts of funding on fire suppression, usually prioritizing fire management only where people and property are at risk. Alaska accounts for one fifth of all burned area in the U.S. annually, but it receives only four percent of federal funding for fire management. Limiting fire size and burned area

through proper management can be effective at reducing emissions.

What this means for boreal fire management

To prevent worsening emissions, fire management practices will have to be adjusted to not only protect people and property, but also to address climate change. Fire suppression in boreal forests is an incredibly cost-effective way to reduce emissions. The study found that the average cost of avoiding one ton of carbon emissions from fire was about \$12. In Alaska, that means investing an

average of just \$696 million per year over the next decade to keep the state's wildfire emissions at historic levels.

Increasing wildfires also pose an outsized threat to Alaska Native and First Nations communities, who may become increasingly isolated, and may lack the resources to evacuate quickly if wildfire encroaches on their lands. Many Alaska Native people already play a crucial role in existing wildfire crews, and investing in more fire suppression could create additional job opportunities for Indigenous communities.

In the news: highlights

PERMAFROST PATHWAYS MEDIA HIGHLIGHTS

A *New York Times* article highlighting the launch of Permafrost Pathways featured project leads Dr. Sue Natali, Dr. John Holdren, and Robin Bronen (Alaska Institute for Justice), who spoke about the significance of the 6-year project. The article has been shared over 1,100 times and was the lead story in the US Arctic Research Commission's April 12 email newsletter.

A *Time* newsletter featured a Q&A with Dr. Sue Natali about Permafrost Pathways, and how funding through TED's Audacious Project will help them achieve their goals.

Dr. Sue Natali, Dr. John Holdren, and Robin Bronen were quoted in an article from *Arctic Today* about Permafrost Pathways' aims to monitor, mitigate and adapt to Arctic-wide thaw.

Dr. Anna Liljedahl was quoted in a *Grist* article about thawing permafrost, which also mentioned her work with Permafrost Discovery Gateway.

Dr. Foster Brown co-authored an OpEd in *A Gazeta do Acre* (Brazil) warning about a coming severe drought in southwest Amazonia.

Polar Impact, an inclusive network of racial and ethnic minorities and allies in the polar research community, published a feature on Dr. Jacqueline Hung.

Board member Izabella Teixeira was quoted in the *New York Times*' Climate Forward newsletter from April 15, offering her thoughts about former Brazilian President Luiz Inácio Lula da Silva's perspective on climate issues. She previously served as one of Lula's environment ministers.

Dr. Jen Francis's participated in a congressional briefing with Environmental and Energy Study Institute, centered around the polar vortex.

A post on *TED Blog* covered Dr. Sue Natali's standout TED talk presenting Permafrost Pathways. A widely-syndicated *Reuters* article quoted Dr. Sue Natali on her challenges shipping instrumentation to field sites in Russia.

An article from IPAM Amazônia showcased a recent workshop on GIS (Geographic Information Systems) for Indigenous fire brigade members, supported in part by Woodwell.

A post on TED Blog named Woodwell Climate as a 2021-22 Audacious Project grantee for our work integrating permafrost into our global solution for climate change.

Dr. Jen Francis was live on NPR this week, along with Naomi Oreskes, for 40 minutes of Q&A about tackling the climate change crisis. She was also quoted in an article from *Associated Press News* countering climate doomism, which was syndicated to over 60 news outlets internationally.

Dr. Thomas E. Lovejoy, Woodwell's longest-serving director and inaugural Distinguished Ambassador, was remembered in an obituary from *National Geographic*.

An article from *EcoWatch* quoted Dr. Wayne Walker on the imperative of protecting our standing forests.

Dr. Mike Coe was quoted on the importance of forests for preventing the worst-case scenarios of global warming in an article from *La Stampa* (Italy), as well as an article from *Scinexx* (Germany).

Dr. Sue Natali's interview with *Time* was quoted in an article from *Inside Climate News* discussing the implications of the Russia-Ukraine conflict on climate science.

An *Inside Philanthropy* article named Woodwell as one of the recipients of MacKenzie Scott's recent donations.

Donations play an important role in securing the future of Woodwell Climate Research Center's work—and help safeguard the health of our planet for generations to come.

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**Woodwell Climate
Research Center**

149 Woods Hole Road
Falmouth, MA, 02540-1644

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