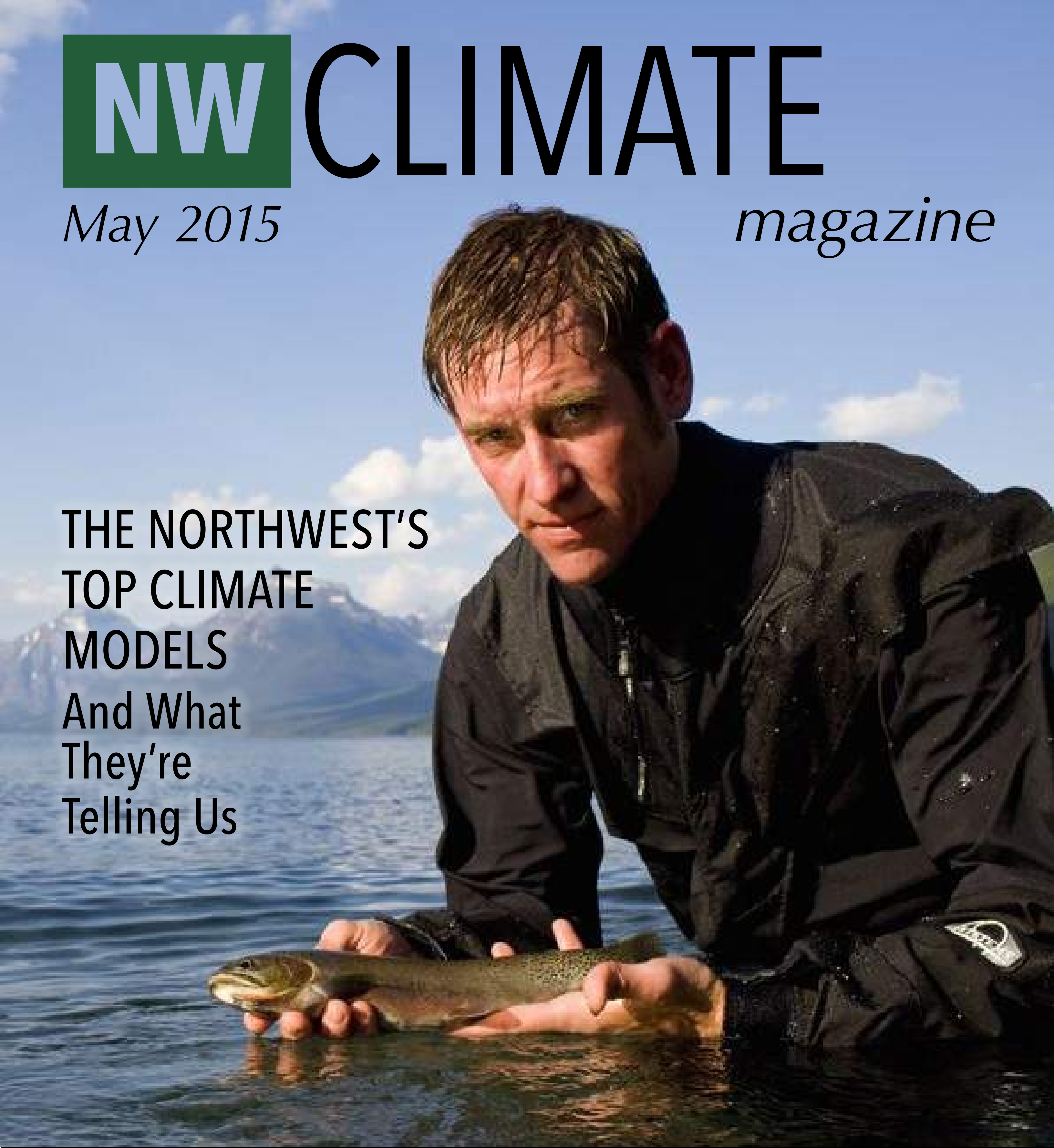
NW CLIMATE magazine

May 2015



THE NORTHWEST'S TOP CLIMATE MODELS

And What They're Telling Us

Warming Favors Introduced Fish Over Native Salmon

Northwest Tribes Link Climate Change to Community Health

Preparing for Climate Change on the Oregon Coast

Stories about federal climate change research in the Northwest

NW CLIMATE magazine

May 2015

Letter From the Editorial Board

Feature

Profiles

Departments

Extras

Contributors

Editorial Board

Editors

Design

Audra Mote, Nathan Gilles, Lisa Hayward, and Meghan Kearney

Photography

Noah Clayton, Dudley Chelton, Erika Sutherland, Natalie McNear, David Lawrence, Ivan Phillipsen, Robert Al-Chokhachy, Robin Munshaw, Patrick Corcoran, Maureen Ryan, Laura Lundquist, LuRay Parker, Jeff Hicke, Jim Gibson, and the Swinomish Indian Tribal Community

About

Northwest Climate Magazine is a joint effort of the Northwest Climate Science Center, the Pacific Northwest Climate Impacts Research Consortium, and the North Pacific Landscape Conservation Cooperative.
Our goal is to tell stories and share information about a variety of federally funded climate science and adaptation efforts underway in Oregon, Washington, Idaho, and Montana.

Special Thanks To: *Lee Sherman, Nick Houtman, Rachel Cocker, and Jennifer Hinds*

On the cover: *U.S. Geological Survey scientist Clint Muhlfeld holds a genetically pure westslope cutthroat trout in the Middle Fork of the Flathead River, western Montana (see Shifting Bass-Lines, page 32). (Photo: Noah Clayton, U.S. Geological Survey)*

Please direct correspondence to:

Northwest Climate Science Center
C/O Lisa Hayward
University of Washington
Box 355674
Seattle, Washington 98195
lhayward@uw.edu

Member: *University Research Magazine Association*

From the Editorial Board

Gustavo Bisbal, NW CSC

John Mankowski, NPLCC

Philip Mote, CIRC, NW CSC

Eric Salathé Jr., NW CSC

Dear Reader,

We hope this new annual publication, *Northwest Climate Magazine*, will help share our stories about climate research and improve coordination and collaboration among federal, state, tribal, university, and non-governmental groups across the Northwest. Collaboration is central to our shared goal of building resilience to climate change for our region's natural and human communities.

Climate change threatens our way of life in the Northwest on many fronts. The best scientific understanding indicates that climate change will impact everything from the region's ecology and agriculture to its basic infrastructure, culture, economy, and community health. We still have time to avert the worst effects, but some change is inevitable. To successfully adapt to these changes, we must coordinate our efforts and work across the institutional boundaries that divide government agencies, Tribes, universities, non-governmental organizations, and the private sector.

The Northwest benefits from strong institutional and scientific alignment of the federal regional climate organizations: the National Oceanic and Atmospheric Administration's Regional Integrated Science and Assessment, known as the Pacific Northwest Climate Impacts Research Consortium (CIRC); the Department of the Interior's Northwest Climate Science Center (NW CSC) and three Landscape Conservation Cooperatives the North Pacific LCC (NPLCC), Great Basin LCC (GB LCC), and Great Northern LCC (GN LCC); and the U.S. Department of Agriculture's Regional Climate Hub (NRCH).

Despite strong alignment, each federal regional climate organization maintains a distinct mission, funding structure, system of governance, target audience, method of setting priorities, and set of deliverables—many of which are described in the profiles in this issue. In part because of our differences, our respective federal organizations have done an excellent job collaborating effectively to build synergies and avoid redundancies. We developed this magazine as one of the many ways to share our work and continue to advance a common cause around climate change adaptation.

The Northwest has a rich history of regional climate change research and stakeholder engagement that gives us the capacity to use new data in ways that are mutually beneficial and relevant to our shared concerns. The stories included in this first issue are examples of some of those successes—from using stream temperature data to help plan protection for native salmonids to safeguarding coastal communities from intensifying storm surges.

Sincerely,

Gustavo Bisbal (NW CSC), John Mankowski (NPLCC),
Philip W. Mote (CIRC/NW CSC), & Eric P. Salathé Jr. (NW CSC)

Researchers conduct fieldwork in high alpine wetlands below Mt. Rainier. (Photo: ©Maureen Ryan, University of Washington)

High and Dry?

By Meghan Kearney

Northwest Mountain Amphibians and their Changing Wetlands

For as long as she can remember, Maureen Ryan has been fascinated by mountains. As an English major, Maureen used to spend her time outdoors as a mountaineering guide. This eventually led to a passion for mountain wetland conservation and a career in science.

"I love the mountains," says Ryan. "I've spent my entire adult life in the mountains, fascinated by species in extreme environments."

Now a freshwater ecologist and conservation biologist with the University of Washington, Ryan is one of several researchers spearheading conservation in the Northwest's *montane*—the scientific term for mountains—wetlands in an effort to track how their amphibian residents are responding to our region's changing climate.

Each year from Mt. Rainier to Mt. St. Helens the seasons run their cycle as the snow perched atop the Northwest's majestic, high elevations melts, eventually winding its way to the Pacific Ocean. Along its gravity-propelled journey, this water fills montane lakes and streams, providing essential habitat for species such as alpine frogs and salamanders, while also feeding streams carrying young salmon—not to mention fresh water for towns and farms—downstream. Sadly, this process is now threatened by climate change, which has been diminishing the region's snowpack. Especially imperiled are montane amphibians. Here Ryan and others hope to make a difference by providing a guide to help land managers develop adaptation strategies. But Ryan says studying montane wetlands is challenging, and for that reason they remain one of the most under-examined ecosystems on Earth.

"Many people find that montane wetlands are too complicated to measure at a large scale," says Ryan.

The problem, according to Ryan, is this: effectively studying montane wetlands requires that a huge amount of research happen on site, which has often meant researchers trekking through hard-to-access, rough mountain terrain, a barrier to entry if ever there was one. Recognizing this difficulty, Northwest researchers are collaborating to tackle this challenge.

"This project was such a clear example of one where we might see something proactive, on public lands and in collaboration with agencies"

The effort began in 2011, when Alan Hamlet, then with the University of [Washington's Climate Impacts Group](), began a unique climate impacts project. Hamlet wanted to understand how climate change was affecting montane wetlands in Oregon, Washington, and California. He later received further funding from the North Pacific Landscape Conservation Cooperative (NPLCC) and the Northwest Climate Science Center (NW CSC) to computer model the region's montane wetlands.

Hamlet's effort has produced a series of computer tools, simulating historical wetland behavior with climate variability. He then used these tools to help assess the impacts of future projected climate change into the 2040s and 2080s. His results project future decades will see warmer and drier summers, which, coupled with consequent reductions to snowpack, will lead to water draining from the wetlands much earlier in the year, reducing wetland water levels, increasing rates and likelihood of drying, and shortening periods of time that wetlands will hold water. These results paved the way for tackling the unique challenges of montane wetlands.

Later, funding from the NPLCC allowed Ryan to extend the application of models developed by Hamlet's research to specific sites in Mt. Rainier and Olympic National Parks, where researchers are exploring how the drying of high-elevation wetlands results in habitat loss for species, including frogs and salamanders. These species are hidden gems, says Ryan, dependent on heavy snow cover and high-water ponds.

"I'd spent years in these mountains." Ryan adds, "I can't believe how many of those little ponds I walked by without noticing them."

An unknown hybrid species of salamander captured in Olympic National Park, Washington. (Photo: ©Robin Munshaw, Simon Fraser University)

Ryan and Hamlet's work is now providing a sort of playbook to help land managers develop adaptation strategies. Managers at North Cascades National Park have already employed the project's results into their management practice for dealing with introduced fish species. The study is also being expanded into the Midwest, focusing on Indiana and Illinois' Kankakee River basin.

Continued support from climate-science agencies and the work of climate scientists are producing practical results that will continue to assist the preservation of montane landscapes, which play an integral role in the functioning of environments throughout the Pacific Northwest.

"This project was such a clear example of one where we might see something proactive, on public lands, and in collaboration with agencies," says Ryan. "It has been a great opportunity to contribute to, learn from, and work with folks who think about these landscapes deeply and have been working for decades to protect them."

The NPLCC and NW CSC provided support for this project in an effort to carry out our missions to develop and provide climate science information to inform management decisions. Coordination on this project helped advance our missions through efficient collaboration and leveraging of funds.

NWC

Several Northwest, mountain frog species are species of concern

The Cascade Frog, listed as a Washington Species of Concern and an Oregon Critical Species (Photo: Oregon Caves National Park)

The Spotted Frog, listed as an Oregon Critical Species (Photo: U.S. Forest Service)

Mountain Yellow-Legged Frog, federally listed (Photo: U.S. Forest Service)

Sierra Nevada, Yellow-Legged Frog, proposed for federal listing (Photo: ©Natalie McNear, Flickr Creative Commons)

Western Toad, Oregon Critical Species (Photo: ©Ivan Phillipsen, Oregon State University)

Yosemite Toad, proposed for federal listing (Photo: Lucas Wilkinson, U.S. Forest Service)

Great Northern Landscape Conservation Cooperative

HISTORY

The Great Northern Landscape Conservation Cooperative (GNLCC) is one of 22 Landscape Conservation Cooperatives initiated by Secretarial Order No. 3289 in 2010 to address emerging landscape-scale conservation challenges.

MISSION

A landscape that sustains its diverse natural systems to support healthy and connected populations of fish, wildlife, and plants; sustains traditional land uses and cultural history; and supports robust communities.

FOOTPRINT

Portions of Idaho, Montana, Oregon, Washington, Wyoming, British Columbia, and Alberta.

THE **conservation challenges** of the 21st Century are more complex than ever before. In addition to those previously confronted at the local level, widespread stressors, such as drought, climate change, and large-scale habitat fragmentation, are complicating efforts to plan and conduct conservation. These complex stressors don't just affect isolated places or individual species; they impact entire landscapes and multiple resources simultaneously.

For a variety of reasons, traditional natural resource management infrastructure has not been designed to confront these landscape-scale challenges. **The Great Northern Landscape Conservation Cooperative** (GNLCC) is charged with recognizing and addressing those challenges, as well as identifying and overcoming existing institutional limitations to working at landscape scales. Covering over 110 million hectares in the Inter-mountain West of North America—from central British Columbia to southwestern Wyoming—the GNLCC is a self-directed partnership comprised of over 30 state, provincial, Tribes, First Nations, non-governmental, and federal (U.S. and Canada) organizations.

The GNLCC identifies critical conservation priorities and science needs, and implements conservation solutions. Since 2010, the GNLCC and partners have invested and leveraged over $20 million delivering science and conservation design for species as diverse as grizzly bear, bull trout, and sage grouse, as well as the montane, aquatic, and arid habitats they depend on. To further connect conservation science efforts, the GNLCC co-led development of the Landscape Conservation Management and Analysis Portal, also known as ScienceBase, as the information delivery platform linking 14 LCCs and all the Climate Science Centers. *For more information, visit greatnorthernlcc.org*.

Robert Al-Chokhachy, a U.S. Geological Survey scientist, and his crew collect field data to inform the prioritization of conservation strategies for Yellowstone cutthroat trout in a changing climate. (Photo: ©Patrick Uthe, Montana State University)

Shoring Up for Climate Change

By Nathan Gilles

Homeowners Prepare for Climate Change Along the Oregon Coast

The Pacific Ocean comes crashing in. Just a sliver of homes nestled between the raging sea and Highway 101, the tiny coastal town of Neskowin, Oregon, is soon overwhelmed.

Storming up Hawk Creek, the salty deluge cascades over the Salem Avenue Bridge, the only public access to the highway and safety.

This was the scene during the El Niño of 1997–1998. The climate event raised local sea levels by several centimeters and coincided with powerful storms, leading to flooding and area erosion the likes of which Neskowin's residents had never seen before. But this snapshot could be as much a preview of things to come as a glimpse into the recent past.

By 2100, depending on the local terrain, sea levels along the Northwest coast will rise by anywhere from less than half a meter (1.5 feet) to as much as one-and-a-half meters (4.5 feet), according to current research. This means that by century's end, the Pacific is likely to inundate the coast by as much as 50 meters (164 feet) in some places. The conclusion is inescapable: the Northwest's coastal communities are at risk. But Neskowin residents and others in Oregon's Tillamook County aren't letting the dire projections drown their hopes. Instead, they're adapting. And they're getting some help from the Pacific Northwest Climate Impacts Research Consortium (CIRC).

Funded by the National Oceanic and Atmospheric Administration, CIRC focuses on research that expands the state of the science while helping Northwestern residents adapt to climate change. (See Profile on page 27.)

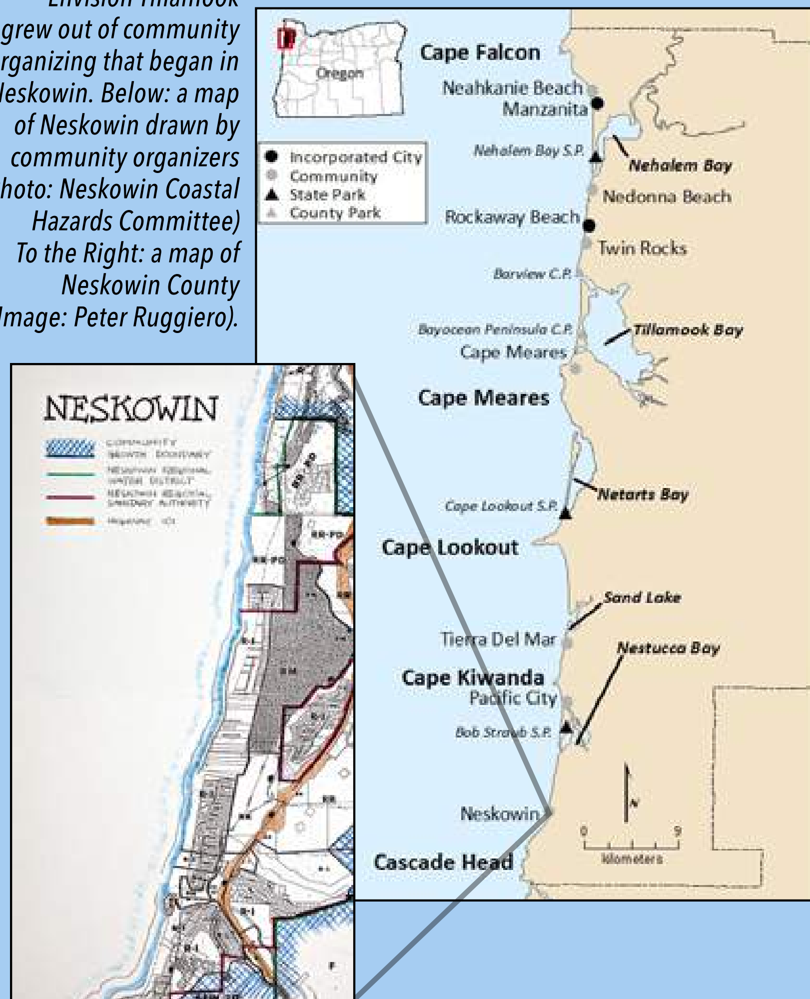
Image on the previous page: From 1965 to 2000, Tillamook County, Oregon, saw massive beach erosion. Neskowin's beach was a hot spot for this erosion, losing roughly 2 meters (10 feet) of its beach a year to the Pacific Ocean–about 70 meters (230 feet) in total from 1965 to 2000. Here beach-protecting rocks, known as riprap, have been placed in front of a Neskowin home to slow the process. (Photo: Patrick Corcoran, Oregon Sea Grant)

Through its Envision Tillamook County Coastal Futures project, Envision Tillamook for short, CIRC is helping the people of Tillamook County—from area homeowners and businesses to local governments and state planners—visualize how both climate change and local planning will affect their natural and human landscapes. To accomplish this, Envision Tillamook researchers are modeling all 100 kilometers (62 miles) of Tillamook County's coastline in Envision, a powerful computer program developed by CIRC researcher John Bolte. Envision is revealing how area landscapes are projected to change as population grows and sea levels rise.

Peter Ruggiero, Envision Tillamook's lead researcher, says that to do the modeling right his team had to take the science directly to the people of Tillamook County.

"When I designed the project it was with the CIRC philosophy in mind; it was about co-developing usable science," says Ruggiero.

Envision Tillamook grew out of community organizing that began in Neskowin. Below: a map of Neskowin drawn by community organizers (Photo: Neskowin Coastal Hazards Committee) To the Right: a map of Neskowin County (Image: Peter Ruggiero).



Ruggiero, an associate professor at Oregon State University's College of Earth, Ocean, and Atmospheric Sciences, has studied the impacts of climate change and variability on Oregon's coast for the last decade. Through a series of community meetings and one-on-one interactions with local residents, Ruggiero, Bolte, and the rest of the Envision Tillamook team have gotten feedback from Tillamook residents on the modeling project as it progresses. Guy Sievert, a Neskowin resident, says he's been impressed with the earnestness of the researchers and their effort.

"I've been very pleased with how receptive the group has been to input," says Sievert.

What's come out of the meetings is a series of likely future scenarios that mix climate projections—from climate-change-induced rising sea levels to growing wave heights—with local human impacts—including projections for population and infrastructure growth till the century's end. But the program goes a step further.

Envision—which is currently being used on two other CIRC projects—is allowing Tillamook County to imagine the different planning paths they might take as the climate changes. Possible paths (see the graph below) include changing and potentially restricting how buildings are sited along the coast. Also included is a path where current rules about “beach armoring”—a controversial engineering tool that allows homeowners to protect their beachside properties with rock formations called riprap but limits public beach access—are loosened to reflect the future realities of rising sea levels and beach loss.

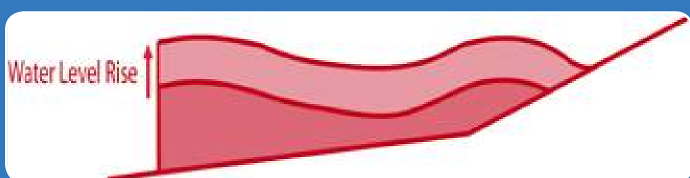
Why all the planning? Tillamook homeowners say it’s about responding to climate change now and into the future.

“Regardless of what you think is causing it, the fact is, we’re already…

Continued on page 17

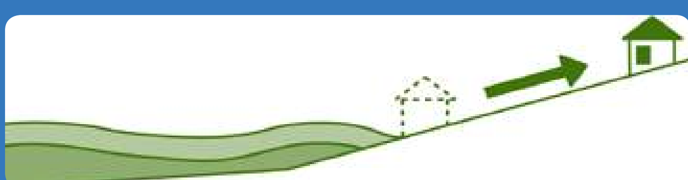
Envision Tillamook’s Future Scenarios

The Envision Tillamook team created five policy scenarios to help Tillamook residents visualize how to plan for climate change and rising sea levels.



Status Quo:
What things will look like if present day policies continue.

Hold the Line: Policies are implemented aimed at preserving existing infrastructure from environmental change. This includes: building flood defenses, building or strengthening shoreline armor (in the form of riprap and other structures), and beach nourishing (adding more sand).



Realign:
Human activities/building habits are changed to suit the changing environment, including relocating infrastructure and/or people.

Laissez-Faire:
Current policies–including Oregon law protecting public access to the beach–are changed or weakened to protect existing homes and infrastructure.

Neskowin:
Policies are implemented in accordance with the Neskowin Coastal Hazards Adaptation Plan. This includes building and/or maintaining flood defenses, and changing human activities.

USDA Northwest Regional Climate Hub

HISTORY

The U.S. Department of Agriculture's seven Regional Climate Hubs were announced in February of 2014 by Secretary of Agriculture Tom Vilsack.

MISSION

To deliver science-based knowledge and practical information to farmers, ranchers, forestland owners, and Tribes that will help them to adapt to climate change.

FOOTPRINT

Alaska, Idaho, Oregon, and Washington.

An employee of the USDA's National Resource Conservation Service amidst dormant berry canes in Oregon.

THE USDA Regional Climate Hubs were created to help farmers, ranchers, and forestland owners maintain production in the face of risks from a shifting climate.

The vision of the **Northwest Regional Climate Hub** (NRCH) is that owners and managers of working lands will be able to easily access the best available information on the direct and indirect effects of climate change for their location to inform their investment decisions.

The U.S. Forest Service, the Natural Resources Conservation Service (NRCS), and the Agricultural Research Service direct the Regional Climate Hubs, collaborating with state and federal agencies, universities, and tribal governments.

NRCH works with Cooperative Forestry, Agricultural Extension, and NRCS Regional Centers to identify the information needs of producers on working landscapes and find the most effective means of delivery. Wherever possible, NRCH seeks to assist existing projects, such as the REACCH project, with communications and outreach of their information and tools.

NRCH is developing a vulnerability analysis to identify primary risks to producers from direct and indirect effects of climate change. It also supports the incorporation of climate risks identified by the Pacific Northwest Climate Impacts Research Consortium into decision support software offered by Oregon State University through AgTools. This will allow farmers to incorporate climate considerations into their cropping and investing decisions.

Risks associated with climate change are many, including a longer dry season, higher probability of flooding, plant and animal diseases, range expansion of invasive species, and larger and more frequent wild fires. NRCH brings together landowners, extension personnel, and climate researchers to develop useful and usable tools that will help landowners conserve resources, improve food security, and ensure that the U.S. rural economy remains environmentally and economically strong and sustainable. *For more information, visit climatehubs.oce.usda.gov/northwest-hub.*

Pining Away

By Lisa Hayward

Climate Change, Mountain Pine Beetles, and the Future of Whitebark Pine

F*or many* millennia, slow-growing whitebark pines have held a place of special influence in their rugged alpine communities. These hardy conifers often live for centuries, thriving in the rocky windswept environment near the tree line in the Rocky Mountains, Cascades, and Sierra Nevadas. In recent years, things have changed. Whitebark pine populations are now declining steeply throughout their range. Climate change, disease, and the mountain pine beetle (a native species whose numbers have exploded in recent years) are largely to blame.

"There's no happy ending," says Polly Buotte, a Northwest Climate Science Center Graduate Fellow at the University of Idaho who studies pine beetle outbreaks in whitebark pines. "There's nothing that people can do on a large enough scale to prevent big change."

That big change, says Buotte, is already here. Half of all whitebark pine trees are now dead or dying. Forest Service scientists estimate that without active management the tree will disappear from 97 percent of its current habitat by 2100. This change won't affect just trees.

As whitebark pines develop, they help other plants establish and survive by maintaining soil and slowing spring runoff by trapping and shading snow. Mature whitebark pines also produce large, rich seeds that feed birds, squirrels, foxes, and grizzly bears (see sidebar on page 16). The loss of this resource may have a domino effect throughout the ecosystem. But resource managers are hoping to help whitebark pines recover. Buotte is among those providing the science aiding this effort.

With support from the Northwest Climate Science Center (NW CSC), Buotte and her advisor, Jeffrey Hicke, a professor of geography at the University of Idaho, spent the last year developing statistical models to better understand the relationship between climate change and mountain pine beetle outbreaks in whitebark pine forests.

Native to western North America, mountain pine beetles occasionally infest pine stands, boring into trees to lay their eggs, a process that spreads a fungus and is often fatal. A tree infested with mountain pine beetles cannot be saved, and its needles eventually turn from green to red.

In recent years, the U.S. West has been banded with red stands of dead trees. Yet in the past beetle outbreaks were less disruptive. For ages, the mountain pine beetle has been in a state of equilibrium with its environment, acting as what's known as a "disturbance agent"—recycling trees weakened by drought, fire, and disease and opening clearings in mature stands that support different species and increase forest diversity. What's more, past outbreaks occurred mostly in isolated pockets, while

Image on the previous page: A swath of dead whitebark pines on Hoyt Peak in eastern Yellowstone National Park in 2004. (Photo: ©Jeffrey Hicke, University of Idaho)

overall beetle numbers remained low. Healthy trees defended against invaders by producing pitch cones to physically eject the beetles from their bark. Cold weather, predators, parasites, and diseases also helped keep beetle numbers in check.

However, climate change is now altering the environment in ways that favor beetle epidemics. When beetle populations are high, large numbers of beetles can launch synchronized attacks that overwhelm the defenses of even healthy trees. In these cases, large-scale outbreaks can occur that kill vast swaths of forest.

In order to better understand how environmental conditions such as climate change influence beetle outbreaks, Buotte and Hicke analyzed the relationships between the number of beetle-killed whitebark pines and data collected by weather stations. Their analysis revealed that fall temperatures, winter minimum temperatures, and cumulative summer rain over a two-year interval were important factors for predicting beetle outbreaks. The researchers went on to create a statistical tool—a "weather suitability model"—using these three variables. The model predicted historical patterns of beetle outbreak both spatially (across forests) and temporally (over time). Its accuracy was very high, explaining more than 85 percent of the natural variation in beetle outbreaks across the landscape.

"We need to take a portfolio approach and spread out our management efforts to spread out our risk of the unknown."

Next Buotte and Hicke combined their statistical model with downscaled climate projections for the region. This allowed them to calculate future beetle outbreak probabilities under three different climate change scenarios (each depending on a different level of global greenhouse gas emissions). As their number crunching commenced, the two say it quickly became clear that future conditions will be much more conducive to beetle outbreaks. Warmer falls will speed beetle development, while warmer winters will kill fewer beetles and increases in summer drought will weaken tree defenses.

The best hope for whitebark pines, the researchers conclude, may be at the highest elevations, where winter temperatures still get low enough to kill off beetle larvae.

But, says Boutte, there are other reasons for optimism. Even in the areas hardest hit by beetles not all whitebark pines are killed. Some small and medium-sized trees persist (beetles favor large trees)along with a few mature seed-producing trees, whose survival is a bit of a mystery. It may be that these individuals have a rare resistance to beetles and can be used to propagate more beetle-resistant trees to be used in restoration.

Polly Buotte (left) discusses mountain pine beetles with retired U.S. Department of Agriculture Forest Service entomologist Jesse Logan in the Absaroka-Beartooth Wilderness just north of Yellowstone. (Photo: Laura Lundquist, ©Bozeman Daily Chronicle)

Buotte and Hicke's maps of future beetle outbreak probabilities are helping guide conservation strategies for whitebark pine stands. Their results will continue to help managers decide where to invest in measures to protect whitebark pines from beetles, such as releasing chemicals that disrupt the beetles' ability to coordinate attacks, where to plant seedlings, and where to reintroduce fire as part of restoration efforts.

Partners at the U.S. Fish and Wildlife Service, the U.S. Forest Service, the National Park Service, and the U.S. Geological Survey have been involved in the study since its inception and consider the research critical. All groups appreciate having tools that help them make as much impact as possible with their limited conservation resources. Buotte says she's come to see the problem in terms of risk management, much in the same way as the financial sector.

"We need to take a portfolio approach and spread out our management efforts to spread out our risk of the unknown," she says. "We can use science to decide what percentage of our efforts to put where, but we shouldn't forget that we don't know everything, and that there are going to be surprises."

For more information, see the [final report](), watch Buotte's [webinar](), or contact her at pbuotte@uidaho.edu.

NWC

Whitebark Pines, Grizzlies, and Surprising Signs of Ecosystem Resilience

The fatty, high-protein seeds of whitebark pine feed birds, squirrels, foxes, and bears. (Pine cone photo from Walter Siegmund, Wikimedia; grizzly bear photo by LuRay Parker, U.S. Fish and Wildlife Service.)

Whitebark pine seeds weigh 10 to 60 times more than the seeds from other trees in the same forests. By weight they're roughly half fat and 20 percent protein. They can last for a year or more when buried. Unsurprisingly, they're a precious fall and winter food source for high mountain birds, squirrels, and foxes. Grizzly bears also eat piles of whitebark pine seeds, digging up and then devouring underground caches made by red squirrels. In years with good production, researchers found grizzly bear scat (aka poop) can be anywhere from 50 to 80 percent whitebark pine seeds.

Yellowstone grizzly bears eat so many whitebark pine seeds that tree declines were used as the primary grounds in a 2009 lawsuit against U.S. Fish and Wildlife Service to continue Endangered Species Act protections for Yellowstone grizzly bears after they were delisted in 2007. The courts ruled that more research was needed. As a result the Interagency Grizzly Bear Study Team, led by the U.S. Geological Survey (USGS), was tasked with investigating the role of disappearing whitebark pine in grizzly bear population dynamics.

"Until we did this work the assumption by many, including some on our science team, was that declines in whitebark pine would lead to declines in grizzlies," said Frank van Manen, the USGS wildlife biologist who led the report. "The biggest surprise for us was that everything pointed in the direction of flexibility."

Despite dramatic declines in Yellowstone whitebark pine populations since the early 2000s–with losses of around 70 percent in the age classes that produce seeds–so far there appear to be no negative impacts on the Yellowstone grizzly bear population.

As van Manen explains, grizzly bears are opportunistic generalists. (He and his team have documented grizzlies eating more than 266 different species of plants and animals.) Grizzly bears show enormous adaptability in their diets from year to year, from season to season, and from one area of the ecosystem to another. About one third of Yellowstone grizzly bears have lost all access to whitebark pine resources. Instead they now eat more animal matter–from elk carcasses to army cutworm moths, even ants–without any measurable harm to their health.

While declines in whitebark pine may affect other parts of the food web, signs of resilience in the system are good news for grizzlies and provide some welcome flexibility for Forest Service and National Park Service managers responsible for the natural resources of the Greater Yellowstone area.

SHORING UP FOR CLIMATE CHANGE

Continued from page 12

…experiencing climate change, and it's going to continue to impact the way we live on the coast," says Sievert.

From 1965 to 2000, Neskowin lost some 70 meters (roughly 230 feet) of its beach to erosion. The overwhelming majority of this occurred in the late 1990s, which saw not only a powerful El Niño but also four "100-year storms," so called because, based on past records, in any given year they have a minuscule, one-percent chance of happening.

"The fact is, we're already experiencing climate change, and it's going to continue to impact the way we live on the coast."

Responding to the dangers on their doorsteps, Sievert and other Neskowin homeowners took action. In 2009, with the county's backing they formed the Neskowin Coastal Hazards Committee (NCHC) to push for stronger building codes to protect both property and people facing coastal hazards and climate change.

But to make their case to area planners, the NCHC knew it needed some scientific muscle. They found an ally in Ruggiero, whose work would later become essential to two climate adaptation efforts—one for Neskowin and one for all of Tillamook County. As of this writing, what's being called the Neskowin Plan is currently under review by the county. Ruggiero says Envision Tillamook grew out of this earlier work with Sievert and others. The effort got a boost from Oregon Sea Grant, whose Patrick Corcoran is a co-principal investigator on the project. Ruggiero says the idea was to try to extend the efforts of Sievert and the NCHC to the rest of Tillamook.

Sievert, who admits he was initially skeptical about what a modeling effort could add to the NCHC's efforts, says he's pleased that Ruggiero and Bolte are aiding his group's planning work. But, he says, more planning will be needed as the climate continues to change. This will be especially important, he adds, for towns to avoid infrastructure snafus, such as Neskowin's Salem Avenue Bridge, which, he points out, has long been not just the only public access to the highway, but also carries sewer and telephone lines into town. A second access to the highway is currently under construction due in large part to the efforts of Sievert and other concerned residents.

"I think the Envision [Tillamook] program is a natural extension of the things we have done locally in Neskowin," says Sievert. "I think what it does is keep Tillamook County at the forefront of planning for these hazards."

For more information, visit the project's website.

NWC

BACK TO THE FUTURES

What the Ambitious Integrated Scenarios Project Says About the Northwest Under Climate Change; How Do Climate Models Work; and What the Heck is Downscaling Anyway?

By Nathan Gilles

L*et's start* with the basics. Our planet is warming. The Northwest is no exception.

"The Northwest will be dramatically different," says climate researcher David Rupp.

It's around 10 AM on April 17, 2014, and Rupp, a lanky, gray-haired man in his early 40s, is presenting to a packed conference room in Portland, Oregon. Next to him a screen shows a graph—in orange, yellow, and red—displaying a conspicuous spike in the Northwest's future temperatures.

By 2100, explains Rupp, the region's average temperatures are expected to be anywhere from 2 to 15 degrees Fahrenheit warmer than today's. The reason for this rocket-like departure from the norm: greenhouse gases.

"In some cases, the temperatures simulated here are not just above what we're used to seeing, they're above the maximum temperatures we've seen in the past. We're looking at consistently high temperatures," says Rupp.

Rupp isn't the only one doling out bad news. Throughout the day, other researchers will demonstrate how rising temperatures are expected to make future precipitation far more likely to fall as rain and not as snow; bad news for ecosystems and human communities that rely on snowpack for their water needs. Other researchers will show how a warming climate will significantly transform the Northwest's forests, a process aided by large, destructive fires. And this just scratches the surface.

Yet on this morning, the climate-changed world the researchers are depicting feels far away. Outside it's just another cold, rainy Oregon day. However, none in attendance are fooled by the familiar weather. That's because this audience is made up of resource managers from across the Northwest. These men and

Image on the previous page: Who says science can't be art? Pictured here is a montage of the climate model evaluation work that kick-started Integrated Scenarios. (Image: David Rupp, "Evaluation of CMIP5 20th century climate simulations for the Pacific Northwest USA", Journal of Geophysical Research: Atmospheres, VOL. 118.)

women on the frontlines of climate adaptation have come to hear the results of an ambitious climate science effort that could change how climate adaption gets done in the Northwest.

The project is Integrated Scenarios of the Future Northwest Environment, a collaborative venture that brought together scientists from five separate Northwest climate research organizations. Integrated Scenarios' goal was deceptively simple: explain what the latest climate science says about the Northwest's future climate, vegetation, and hydrology. Getting the answer would take some doing.

What follows is the story of Integrated Scenarios and, hopefully, something more.

As the researchers featured here are keenly aware, the general public has nearly no idea what they do. This misunderstanding has been aided and abetted by news outlets' tendency to highlight climate science's results while neglecting its methods. By providing a rough sketch of Integrated Scenarios' methods, this story (with humor and humility) aims to buck that trend.

New Models, New Needs

Let's leave the conference. It's now 2011, the Pacific Northwest Climate Impacts Research Consortium (CIRC), a National Oceanic and Atmospheric Administration-funded climate research organization housed at Oregon State University (OSU), in Corvallis, Oregon, has just conducted a survey of Northwest resource managers. It reports many want more information about what the Northwest will look like under climate change.

A worldwide effort called the Coupled Model Intercomparison Project Phase 5 (CMIP5) is deluging the climate research and adaptation community with a tsunami of computer-generated climate model outputs, leaving many resource managers wanting to know which new models they should use in their adaptation work.

"Integrated Scenarios really comes out of that survey," explains CIRC co-lead Philip Mote. "The survey highlighted that there's a lack of good information available to resource managers about what models to use and what climate change is expected to look like."

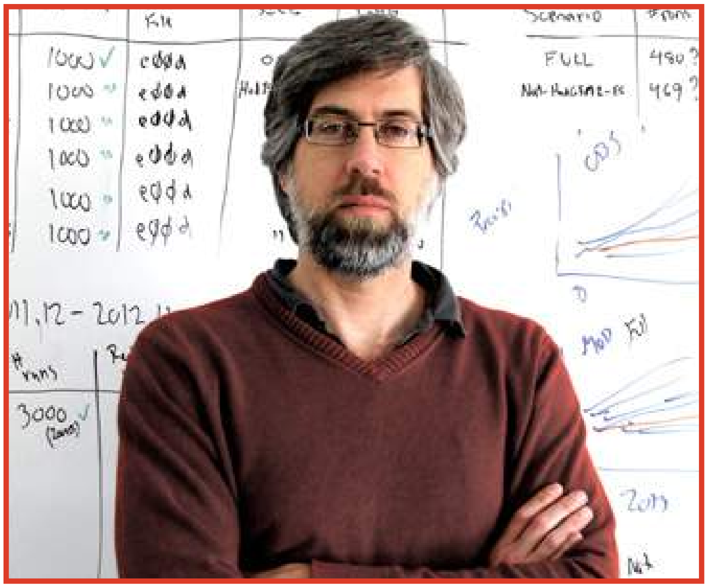
To get the best science to managers, a project was needed that was systematic, interdisciplinary, and, well, integrated. That's because an accurate picture of a climate-changed Northwest would have to include not only computer-modeling the region's climate but its vegetation and hydrology as well.

Here's why: Imagine you manage a large water utility. Knowing climate projections for your region is a good start. These can tell you about warming temperatures or how much precipitation might fall on your watershed. But climate modeling alone isn't the whole story. For other important details, such as how stream flow and vegetation might change, you'll need separate vegetation and hydrology modeling. For all these computer simulations to come together, the modeling needs to move assembly-line-fashion, with each discipline using the same climate scenarios and models. As Mote puts it, "Basically, everyone needs to be on the same page." Mote decided to do just that.

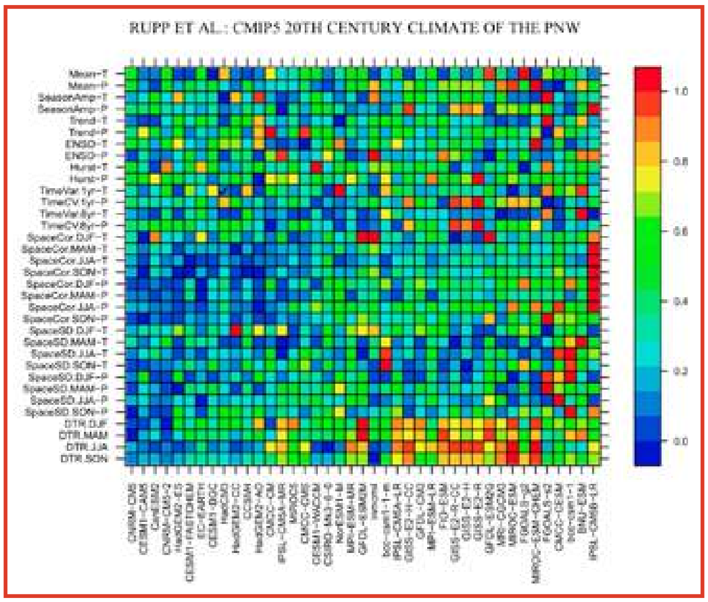
To kick-start the effort, Mote secured CIRC funding, later receiving extra-backing from the Regional Approaches to Climate Change project, the U.S. Forest Service, and the Northwest Climate Science Center. He then assembled his team of climatologists, hydrologists, and vegetation modelers. Next up: finding the right models.

The Northwest's Next Top (Climate) Model(s)

Regardless of what you might've heard, climate forecasting—like weather forecasting—isn't about predicting the future. There's too much uncertainty for that. Instead



David Rupp (Photo: Climate Impacts Research Consortium)



This graph–also pictured at the start of this story–depicts the climate model vetting work done for Integrated Scenarios. Models are listed at the bottom. On the left are meteorological measures, including temperature and precipitation. The graph depicts what's known as relative error, in this case how well the models match historical measures for the Northwest. Here warm colors depict higher degrees of error and cooler colors less error. The models are organized from left (least error) to right (most error). (Image: David Rupp, "Evaluation of CMIP5 20th century climate simulations for the Pacific Northwest USA", Journal of Geophysical Research: Atmospheres, VOL. 118)

climate researchers—like weather forecasters—deal in probabilities. These produce climate projections (not predictions) that, in turn, create scenarios for the future, also called future scenarios or just plain *futures* (plural).

Futures are created by employing computer-generated models of the climate that create what are, in effect, extremely long weather simulations that, when averaged over several decades, create climate projections. Unlike weather forecasts, which are interested in daily and weekly forecasts, climate futures look at forecasts over decades.

There are dozens of climate models, creating hundreds of differing—and often conflicting—projections. Not surprisingly, the problem researchers face is which to choose.

"One of the questions people ask is, 'Of these different climate projections coming from these models, which should we believe? Which projections are more credible, and, hence, which models are more credible?' Our work tries to address that," says David Rupp from his OSU office.

Rupp—besides discoursing on dire temperature projections—evaluates climate models for CIRC. His work was step one in Integrated Scenarios' assembly line, but you should picture him as a bouncer, selecting just the right patrons to enter an exclusive club.

As any climatologist will tell you, not all climate models, called *global climate models* or GCMs, are created equal. They differ in design and assumptions. Rupp wanted to know which GCMs were the best fit for the Northwest.

He puzzled this out by comparing how accurately the new CMIP5 models simulated the Northwest's climatic past. His reasoning was straightforward. How well GCMs replicate recorded meteorological conditions—the decades of data from regional weather stations—is considered the best test for how accurately these same GCMs will model future climate. Following months of analysis, Rupp found his chosen few, a mere 20 GCMs that he deemed right for this region. Next on the team's to-do list: mixing in emissions.

Emissions and Global Warming

Climate change begins with warming that's caused by energy from the sun getting trapped by greenhouse gases in the Earth's atmosphere. Okay, you know that much. What you don't know is how much greenhouse gas people will continue dumping into the sky. Don't feel bad. Nobody knows this, climatologists included. But climatologists do know how to account for this uncertainty, by using emissions scenarios.

To account for emissions uncertainty, climate researchers have agreed to standardize their work by using a suite of possible emissions scenarios called the *Representative Concentration Pathways*, or RCPs. A product of the Intergovernmental Panel on Climate Change, the world's leading climate organization, RCPs—which range from low to high—get plugged into climate models to account for the how-much-and-for-how-long problem of greenhouse gases emission uncertainty.

The RCPs start with RCP 2.6. This is a low emissions scenario, producing little to no warming. (It assumes humanity sharply curtails emissions. It's widely considered as woefully unrealistic, but shows what would be required to avoid a 'dangerous' global temperature rise of 2°C (3.6° F.) At the other end there's RCP 8.5. This is the worst-case, high emissions scenario, producing rapid climate change. (This, regrettably, is the path many climatologists calculate we're stumbling down.)

Integrated Scenarios' researchers selected two RCPs for their model runs: RCP 8.5 and the far more desirable RCP 4.5, a sort of middling scenario that assumes we cut emissions before it's too late.

Combining the two scenarios with their chosen 20 GCMs, they then ran computer simulations for the Northwest from 2006 to 2100, producing 40 total scenarios. However, this wasn't enough detail for the team. Enter *downscaling*.

Model Globally, Downscale Locally

As "global" suggests, global climate models focus on the big picture. They do this by dividing the world into a series of square grid cells, averaging roughly 375 km (233 miles) to a side. (To put these numbers into context, modeling the Northwest—from the Pacific Ocean to the western Rockies—only takes three grid cells.)

Integrated Scenarios models used GCM cells that were 200 km (124 miles) to a side. In this "coarse resolution," the Rockies appear as an extended knoll. The Cascades barely register. That's not very detailed. And it's not very helpful, especially for resource managers, who focus on smaller, local features such as forests, basins, and watersheds. Here's where downscaling comes in.

"Downscaling is a means to translate the coarse resolutions of GCMs down to local scales, where they can be used by the vegetation and hydrologic modelers," says John Abatzoglou.

Abatzoglou, a climate scientist and self-described "weather weenie" at

John Abatzoglou (Photo: University of Idaho)

University of Idaho in Moscow, Idaho, along with Katherine Hegewisch, ran Integrated Scenarios' downscaling using his own creation, a downscaling method called the Multivariate Adaptive Constructed Analogs (MACA). As with climate models, there are dozens of ways to downscale. MACA was chosen for its ability to simulate complex terrain. It fit snuggly with the mountainous Northwest.

With MACA, Abatzoglou refined Rupp's coarse model runs into a series of high-res, 6-km-by-6-km

(4-miles-by-4-miles) grid cells. This refining involved "bias-correcting," which—similar to Rupp's vetting—compared the GCMs' performance against regional observations.

"Basically, we forced our GCM data to adhere to the statistical behavior of our observed data," says Abatzoglou. "We did that by adjusting our 20th century runs to the observed datasets."

Bart Nijssen (Photo: Northwest Climate Science Center)

The bias-corrected data was then applied in model runs using the two emissions scenarios for the 21st century. The result: the downscaling threw the Northwest's mountains—Cascades included—into sharp relief. The resulting data was then off to the hydrologists.

Buckets, Champagne, and Hydrology

Hydrologist Bart Nijssen has buckets and champagne on the brain. Nijssen works at the University of Washington's Seattle campus. There, he, Matt Stumbaugh, and Dennis Lettenmaier ran Integrated Scenarios' hydrologic modeling. Like Abatzoglou, Nijssen's beef is with coarse resolution. Enter the buckets.

Early hydrologic models are commonly—and disparagingly—called "bucket models." In them, GCM grid cells work as enormous buckets, catching precipitation. Once full, the buckets "overflow," producing a rough facsimile of stream flow and runoff, but in practice the bucket models proved to be a poor representation of real world hydrology.

"One of the problems with these early models was size. The buckets were just too big," says Nijssen. "Runoff wasn't really produced until the bucket was full. And that didn't always happen."

"One of the questions people ask is, 'Of these different climate projections coming from these models, which should we believe?'"

The solution was to make the buckets smaller, much smaller. For Integrated Scenarios, Nijssen—drawing on Abatzoglou's downscaling—used 6-km-by-6-km cells. If we extend the bucket/coarse-grid-cell metaphor, this is like taking a five-gallon bucket and turning it into roughly 40 pint glasses.

But, says Nijssen, this isn't the whole picture. In early models, these pints rested on a flat and nearly featureless earth. They needed elevation. So hydrologists—Lettenmaier and Nijssen among them—developed models that included elevation. They did this by using regional topographic data to further divide each cell into sets of averaged elevation heights.

For the next step, imagine those pints have subdivided into champagne glasses stacked tower-like, as you might see at a wedding. The bubbly represents precipitation, which, as it fills one glass, spills over into the next, cascading down. Now let's add a caveat, the glasses aren't all stacked in a perfect top-to-bottom manner. Instead they mimic the terrain they model. What's more, the flowing liquid doesn't have a single entry point. (Precipitation as rain or snow doesn't have as steady a hand as a waiter at a wedding.)

Throw in some bias-corrected precipitation data via MACA and—bada-bing, bada-boom—you've got a pretty good picture of the hydrology modeling that was done for Integrated Scenarios using the Variable Infiltration Capacity Macro-scale Hydrologic Model, a Lettenmaier creation he's been perfecting since the mid-1990s.

The Integrated Scenarios' hydrology team ran simulations for the historic period 1950 to 2006 and from 2006 to 2100, again for both the high and medium emissions scenarios. The hydrology team is now in the process of modeling how stream and river flows might change under different climate futures.

What changes in precipitation might mean for the Northwest's vegetation fell to Dominique Bachelet. Her preoccupation: tremendous fires and transforming forests.

Vegetation Models and Changing Forests

For Bachelet, vegetation modeling is as much art as science. She regards her computer models almost as a high-end mechanic regards working on classic cars: elegant but fickle, they're something more than just means of transportation. But, in the end, if they don't get her where she needs to go, looks aren't enough; it's time to pull out the tools.

"What models should do," explains Bachelet, summing up her pragmatism, "is help explain the changes we see. If they don't, then we need to go back to the drawing board."

Bachelet works for the Conservation Biology Institute (CBI), an environmental research organization housed not far from OSU's Corvallis campus. She, along with CBI's Tim Sheehan and OSU's David Turner, headed the vegetation team.

For Integrated Scenarios the modelers employed MC2—the second iteration of a classic in its own right—which Bachelet and colleagues fine-tuned, refined, and fiddled with for decades. MC2 is

Dominique Bachelet (Photo: CIRC)

what's called a dynamic global vegetation model. It combines a biogeochemistry model—exactly what it sounds like—with climate data, in this case Abatzoglou's, to project how vegetation will alter, adapt, and shift with climate change. What makes MC2 especially "dynamic" is how it simulates fire. This requires not only modeling naturally occurring fires but also humans' penchant for extinguishing them. CBI's Tim Sheehan explains.

"Today, when a fire happens, the fire tends to be a larger fire," says Sheehan.

The reason for these big fires—as you've probably heard—is part climate and part years of fire suppression. In the past, unsuppressed fires—as well as prescribed fires by Native Americans—acted as forest custodians, cleaning up unwanted, tinder-box-producing understory vegetation and smaller trees. But following the monster fires of the early 20th century, forest managers (and a bear named "Smokey") started working to put out all forest fires. It's now recognized that this policy created huge fuel loads across the western U.S. that when ignited produce hotter-burning, more destructive fires. Climate enters the picture as warmer springs and summers, which have provided favorable conditions for these large fires to burn.

To capture what these fires might mean in a climate-changed Northwest, the vegetation team ran their simulations both with and without fire suppression. This doubled their simulations from 40 to 80 model runs. They watched as their computing needs ballooned.

What this and Integrated Scenarios' other runs produced was data, lots of data. Curating this data so resource managers can get the most use of it was Integrated Scenarios' final step.

Researchers, Resource Managers, and Big Data

"The data management side of this project has been really challenging," Nijssen tells his audience of resource managers. "And not just for us as producers. But I think it's also going to be challenging for users of the data as well. I'm really interested to see what you want archived out of these models."

It's now late afternoon on that same rainy April day in the packed Portland conference room. Integrated Scenarios' researchers have finished describing their methods and results. Now they're hoping for feedback from their audience of resource managers.

Integrated Scenarios' Findings

What the Project says about the Northwest under Climate Change

Temperature:

End-of-century temperature projections resulting from Integrated Scenarios' model runs range from a balmy 2° Fahrenheit uptick to a stifling 15° F surge, compared with the average temperatures for 1950 to 1999. But whether large or small, these spikes in the mercury are expected to have serious consequences for Northwest hydrology.

Precipitation Projections:

The majority of Integrated Scenarios' model runs are trending toward wetter winters and drier summers. However, only a handful of models project changes that are distinguishable from those measured in the last century. As a climate researcher might put it, natural variability still dominates the signal.

Snowpack:

Due to warming temperatures, future precipitation in the Northwest is far more likely to fall as rain instead of as snow. This spells bad news for fish, farms, and city folk alike, all of which rely on slow melting snow for their summer water needs.

"Basically, what snow affords you is a free, natural reservoir, as opposed to a human constructed one," explains Integrated Scenarios' Bart Nijssen. "So we need to ask 'What does it mean if that reservoir disappears?'"

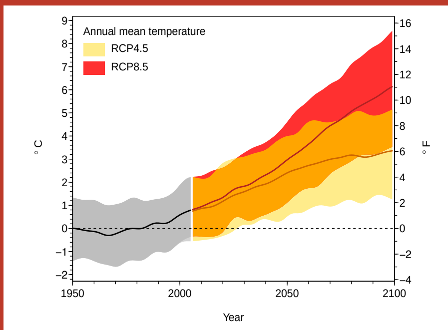
According to Nijssen and his team's modeling work, the Northwest's spring snow will gradually become more and more depleted as this century progresses, with lower elevation watersheds being particularly hard hit by the rising temperatures. This earlier melt will mean larger stream flows in the winter–potentially leading to more flooding–and less soil moisture and increasingly diminishing natural reservoirs during the summer months.

Fire and Vegetation:

By the middle of this century, all 20 Integrated Scenarios' climate models agree: a warmer, drier Northwest will experience larger, more destructive, and more frequent forest fires. The project's findings suggest these fires–which are expected to hit the western Northwest the hardest–will be so disruptive they could spark a kind of ecosystem regime change.

Under a warming climate the now-dominant evergreens, such as the Sitka spruce, will no longer be the best fit for the climate in much of the region's coastal rainforests. Instead, deciduous and subtropical trees–now common along the California coast–will invade the evergreens' territory. Large and destructive fires will aid the invaders–as will pest outbreaks–making the takeover abrupt rather than gradual.

"The take-home message," says Bachelet, "is change in our rainforest region is not going to be smooth. It will be abrupt. It's not if, but when. And it's going to happen sooner rather than later."



Temperature Projections for the Northwest

Here the historical period is shown in gray. Future projections are color-coded, yellow for the lower emissions scenario (RCP 4.5) and red for the high emissions scenario (RCP 8.5). The black line represents the multi-model average for each of the scenarios. Note: the scenarios diverge sharply at mid-century. (Image: ©David Rupp)

The researchers want to know how best to organize their project's prodigious data. The numbers are telling.

Abatzoglou approximates MACA's data alone at around 20 terabytes. The other teams' estimates are equally prodigious. (For context: many computers now come with one terabyte hard drives, ample enough storage for a family-sized collection of digital movies, music, photos, and documents.) The problem, says Abatzoglou, is managing—or curating—the data so resource managers and others in the climate community can get the most from it. For Abatzoglou and his Integrated Scenarios' collaborators this has meant the project doesn't end with publishing results—though several papers have already come from the project. Instead something more is required.

"I think most people think this is sort of a plug-and-play deal, and that they can take the data and walk away," says Abatzoglou from his Idaho office. "But there's really a huge service component."

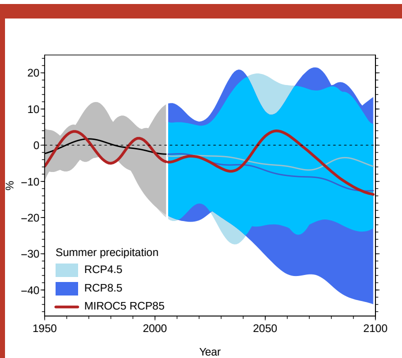
"The fact is we could spend the next century perfecting our climate models, but unless they're available where they're needed, we need to ask, 'What's the point?'"

For Abatzoglou, this service component has already involved hours of additional work following his team's initial downscaling. This extra effort has included building a website to host the data and answering questions and solving problems as they arise, something Abatzoglou jokingly refers to as "tech support". But, he says, all this is necessary if Integrated Scenarios is to fulfill its initial mission of getting the best climate science into the hands of resource managers and other end users.

"I think there can sometimes be issues with getting the best climate science and information to those who need it," says Abatzoglou. "But to me, that's what Integrated Scenarios has been about, that and collaboration and cooperation. The fact is we could spend the next century perfecting our climate models, but unless they're available where they're needed, we need to ask, 'What's the point?'"

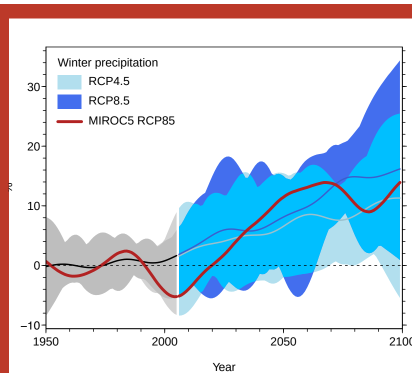
For more information on the Integrated Scenarios project and to access the project's data, visit the website.

NWC



Summer Precipitation

Pictured here are projections for summer precipitation under Integrated Scenarios' two chosen emissions scenarios, the lower scenario (RCP 4.5), pictured in light blue, and the high emissions scenario (RCP 8.5), pictured in dark blue. The multi-model average–shown as the red wavering line–is represented by the climate model MIROC5, which was run using the high emissions scenario. MICRO5 was chosen as a representative model because it tracked closely with the multi-model average. The historical period is marked in gray. (Image: ©David Rupp)



Winter Precipitation

As with the summer precipitation graph shown to the left, here the historical period is shown in gray, emissions scenarios are represented as differing colors of blue, and MIROC5 acts to represent the multi-model average. The trend noted by Integrated Scenarios' researchers is one of wetter winter and drier summers. (Image: ©David Rupp)

The Northwest Climate Science Center

HISTORY

The Northwest Climate Science Center (NW CSC) was established in 2010 as one of eight regional Climate Science Centers initiated by the National Climate Change and Wildlife Science Center at the Department of the Interior's U.S. Geological Survey

MISSION

To become nationally recognized as a best-practice model for the provision of climate science and decision support tools to address conservation and management issues in the Pacific Northwest.

FOOTPRINT

Oregon, Washington, Idaho, and western Montana.

The leadership team and staff of the NW CSC (clockwise from top left): Eric Salathé Jr., Steve Daley-Laursen, Gustavo Bisbal, Greg Gollberg, Philip Mote, Lisa Hayward Watts, Nicole DeCrappeo, Nancy Lee, and Josh Foster.

THE Northwest Climate Science Center (NW CSC) provides actionable climate science and decision support tools to inform conservation and resource management across the Northwest region. The NW CSC does this by providing leadership to strengthen the region's coordinated climate science portfolio and by providing regional audiences with necessary tools and information to promote climate change awareness.

The NW CSC is one of eight regional Department of the Interior Climate Science Centers across the country coordinated through the National Climate Change and Wildlife Science Center (NCCWSC) of the U.S. Geological Survey (USGS). The NW CSC is a consortium of three universities, Oregon State University, the University of Washington, and the University of Idaho.

The NW CSC undertakes a range of activities across five primary arenas: science services, education and training services, communication services, data services, and executive services. It funds projects to meet critical research needs across the region as well as the education and training of graduate students and early career professionals in a range of disciplines related to climate. In order to assess regional climate science needs, the NW CSC developed an inventory of climate science projects from over 12 different Northwest agencies and organizations. These projects are publicly accessible through Data Entry for Project Tracking and Highlighting (DEPTH), a web portal created by NW CSC and NCCWSC. DEPTH helps coordinate efforts across agencies and avoids duplication, while highlighting research gaps. *For more information, visit nwclimatescience.org.*

The PNW Climate Impacts Research Consortium

HISTORY

In 2010, the National Oceanic and Atmospheric Administration (NOAA) created the Pacific Northwest Climate Impacts Research Consortium (CIRC) as one of 11 regional organizations designed to help build community resilience to climate change.

MISSION

To develop state-of-the-science research while helping Northwest stakeholders adapt to climate change.

FOOTPRINT

Oregon, Washington, Idaho, and western Montana.

ADAPTING to climate change is a long, complex task, requiring climate scientists, policy makers, resource managers, and local community members to work together in open, collaborative conversations. Adaptation also requires pushing the frontiers of climate science. **The Pacific Northwest Climate Impacts Research Consortium** (CIRC) aids both these processes by refining and expanding the science of climate change while simultaneously working to put that science in the hands of Northwest residents, officials, and planners as they adapt to climate impacts today and into the future.

CIRC accomplishes its mission by: presenting its findings in journals and state and national climate assessments; by producing climate, vegetation, and hydrological datasets narrowly tailored to the unique geography and needs of Northwest planners; and by coproducing science in on-going dialogs with stakeholders in an effort to create actionable science that is relevant to their needs and concerns surrounding climate change and adaptation.

CIRC researchers have made their data available via websites, closely curating their data while advising users on a one-on-one basis how it can be employed in individual projects.

In its efforts to coproduce actionable science, CIRC has facilitated close working collaborations with researchers and Northwest stakeholders, extending the reach of CIRC's efforts from the Oregon coast to the mountains of Idaho. In the process, CIRC has worked with groups as varied as concerned coastal homeowners hoping to respond to rising sea levels, Tribes wanting to better understand how climate change is affecting the natural resources essential to their cultures, and large municipal water utilities seeking better data to track how climate change will affect their watersheds. Delivering tailored, actionable science, CIRC continues to expand the state of climate science underlying Northwest adaption efforts.

CIRC is one of 11 regional climate adaptation research groups organized under the National Oceanic and Atmospheric Administration's Regional Integrated Science & Assessments program (RISA). CIRC is hosted at Oregon State University by the Oregon Climate Change Research Institute. *For more information, visit pnwcirc.org.*

CIRC staff pictured here with the staff of OCCRI. (Photo: CIRC)

"Our Bodies and Our Spirits"

By Meghan Kearney

Indigenous Health Through the Lens of Traditional Resources

Traditional foods are more than meals for North America's Tribes and First Nations; they are a way of life. But due in part to climate change, these natural and cultural resources are at risk. Here in the Northwest, Indigenous communities and several regional climate research organizations are hoping to change that.

Along the shores of Skagit Bay in western Washington and Vancouver Harbor in British Columbia, the Swinomish Indian Tribal Community and Tsleil-Waututh Nation have teamed up with the U.S. Geological Survey, North Pacific Landscape Conservation Cooperative (NPLCC), and the Northwest Climate Science Center (NW CSC) to pilot a project aimed at preserving the traditional resources of Tribes and First Nations as they face a changing climate.

Our story begins several decades ago in northwestern Washington. At the time, Swinomish community member Larry Campbell, now a tribal elder, was just a young man. One morning, Campbell joined a friend for a shellfish gathering on Puget Sound's Whidbey Island. All day Campbell, his friend, and other community members gathered traditional foods, including shellfish and salmon. That evening, the tasty foods were prepared for a large feast, a celebration of food, community, and tradition that brought together friends and family from throughout the Swinomish community.

As the feast carried on into the night, Campbell noticed something intriguing. His friend's mom was taking allergy pills as she ate her meal. She was allergic to the traditional food. Confused, Campbell asked her why, if they could harm her, she was eating the shellfish. "Because my spirit demands it," came her reply.

Image on the previous page: Swinomish Indian Tribal Community members during the annual "Paddle to Swinomish" event, a long-standing community tradition. (Photo: ©Swinomish Indian Tribal Community)

This was the moment, Campbell says, that he began to understand the real importance of traditional foods; how they weren't just for eating, but a way to celebrate and give thanks for what the Earth had provided.

"Traditional foods feed our bodies and our spirits," explains Campbell.

Today, Campbell is the Tribal Historic Preservation Officer for the Swinomish, an appointed position he's held for the past 15 years with the goal of preserving traditional foods and other resources so that future generations will be able to enjoy them and carry on traditions that the Swinomish community has celebrated from time immemorial. Campbell is being aided in his current efforts by Jamie Donatuto, the Swinomish Tribe's Environmental Health Analyst.

This collaboration began when Donatuto was an undergraduate at Western Washington University, also Campbell's alma mater. At the time, Donatuto had just received an Environmental Protection Agency grant to study toxins found in shellfish eaten as traditional foods by northwest Washington Tribes; something Campbell, who had been a fisherman for most of his life, first noticed, along with other community members, decades earlier. Campbell, seeing the potential in Donatuto and her project, introduced her to Swinomish community members and helped acquaint her with the history and culture of the Swinomish people.

After years of working together, in 2012 funding from the NPLCC and NW CSC supported the continuation of Campbell and Donatuto's work. This project, titled Correlation and Climate Sensitivity of Human Health and Environmental Indicators in the Salish Sea, pilot-tested a method that can be used the world over as a way to evaluate the health of Indigenous communities and their traditional resources.

Through research and interviews with community members, Campbell and Donatuto tailored a series of indicators, developed together over the past ten years, called *Indigenous Health Indicators* (IHIs), to help frame the context of climate change in the Swinomish Tribal Community and the Tsleil-Waututh Nation of British Columbia. The indicators are as follows: community connection, natural resources security, cultural use, education, self-determination, and calm mind. While particular to the two communities, the process of selecting indicators showcases the intent of the project: to provide a working blueprint for other communities to utilize.

From the start, this project has been different from many past tribal/non-tribal collaborations because it was led first and foremost by the voices of tribal communities.

"I think the community [involvement] aspect of this project really caught the eye of the other Tribes," says Campbell.

Swinomish Indian Tribal Community member with a cockle during a shellfish harvest (Photo: ©Jim Gibson, Northwest Indian Fisheries Commission)

Next in the project, Campbell and Donatuto evaluated how the two communities were experiencing climatic changes through the lens of the IHIs and outlined the impacts for community members. With this community members could rank levels of concern for each IHI based on potential changes. Projected risks to IHIs and community health—in this case threats such as sea-level rise, storm surges, and shellfish habitat loss—will help determine what aspects of community health tribal governments should first focus on, explains Donatuto.

While this work on the Northwest coast remains close to Campbell's heart and home, he hasn't given up taking the project global. Here he is already seeing some success. Minutes before his interview for NW Climate Magazine, Campbell had been talking about his project to a group of interested parties from around the globe.

"We have even heard from a group as far as Australia who were looking to develop a model, and then they found out we are working on one," he says, full of excitement.

Campbell says he has high hopes that his and Donatuto's project will be able to help other indigenous communities as they respond to climate change and other environmental impacts.

Campbell and Donatuto's current project is a small piece of the larger Swinomish Community Climate Change Initiative. This initiative began in late 2007 with a proclamation from the Swinomish Indian Senate directing a response to climate change. The Swinomish Community acted on their proclamation by assessing local impacts, identifying vulnerabilities, and prioritizing planning areas and actions to begin addressing potential effects of climate change. Since 2008, the Swinomish Tribal Community has been a leader in climate change response efforts, not just in the Pacific Northwest but across North America and around the globe.

In 2014, the Swinomish Indian Tribal Community was honored for outstanding tribal governance success with the Honoring Nations Award from Harvard University's Project on American Indian Economic Development. The award recognizes American Indian governments that display positive social, political, cultural, and economic prosperity. Each year, a number of tribal governmental programs are nominated. Finalists are chosen by a diverse panel, made up of individuals from public, private, and nonprofit sectors. Ten programs are then chosen and awarded "Honors" or "High Honors."

In being selected for an award, recipients receive funding to support continuation and expansion of their efforts. The award also promotes the recipient's work to other tribal programs, enabling other communities to learn from and replicate the work.

As the Swinomish Climate Change Initiative continues to move forward, Campbell and Donatuto regularly travel far and wide to share their project structure, results, and successful community engagement with other tribal communities.

"We want this to be a model others can take and revamp as they see fit," says Campbell. "I think we're getting there. The project has opened up new ideas for Tribes and First Nations. It's a way to change how non-tribal agencies look at indigenous health and connections to natural resources; it's a model that can be shared through different cultures around the world."

The NPLCC and NW CSC supported this work in recognition of our government-to-government relationship with Tribes and First Nations, Indian trust responsibilities, and co-management relationships over many natural resources in the region. This is part of a larger effort in the Pacific Northwest to assess the impacts of climate change on resources important for the cultural and subsistence values of our region's native communities. For more information, visit northpacificlcc.org and nwclimatescience.org or contact Jamie Donatuto at (360) 466-1532.

NWC

Traditional shellfish are an important cultural resource of the Swinomish Community, from harvest to ceremonial dinners. These traditional foods represent the Swinomish way of life, and the community seeks preservation of these resources for generations to come.

Shellfish gathering is a tradition passed on from generation to generation in the Swinomish Indian Tribal Community. (Photo: ©NWIFC)

Community members celebrate traditional foods at a community clambake. (Photo: ©NWIFC)

Close-up of a cockle, one species of shellfish inhabiting the shores in the Salish Sea region. (Photo: ©Rob Banes, Swinomish Indian Tribal Community)

The Great Basin Landscape Conservation Cooperative

HISTORY

The Great Basin Landscape Conservation Cooperative (GBLCC) was created by Department of the Interior Secretarial Order No. 3289 issued in 2010. It was established as a self-directed partnership with oversight from the U.S. Fish and Wildlife Service and the Bureau of Land Management.

MISSION

To enhance understanding of the effects of a changing climate and other natural and human impacts across the region and to promote the coordination of science-based actions to enable human and natural communities to respond and adapt to those conditions.

FOOTPRINT

Regions in Nevada and parts of Oregon, Idaho, Utah, and California, including Salt Lake City, Utah, Reno, Nevada, and Boise, Idaho.

THE **Great Basin Landscape Conservation Cooperative** (GBLCC) is a self-directed partnership of agencies, non-governmental organizations, industry, tribal, and state representatives who help connect science information providers with resource managers and science users. The GBLCC complements pre-existing organizations already accomplishing conservation work in the Great Basin by helping to facilitate, enhance, and inform that work.

Four primary goals drive the work of the GBLCC: 1) Provide leadership and a framework linking science and management to address shared ecological, climate, social, and economic issues across the basin; 2) Focus science and management actions to sustain natural resources under changing environmental conditions; 3) Enhance collaboration to integrate science and management among GBLCC partners, particularly as they relate to climate change and other landscape-scale change agents; 4) Promote communication and education.

Since 2011, the Steering Committee of the GBLCC has worked to finalize and adopt a GBLCC charter; identify issue-based working groups; select a leadership team; set priorities for the GBLCC and fund science and manage projects in the Great Basin. *For more information, visit greatbasinlcc.org.*

Shifting Bass-Lines

By Lisa Hayward

Warming Favors Invasive Fish over Native Trout and Salmon

Climate change is rapidly altering freshwater systems across the Northwest as air temperatures warm, patterns of precipitation and snow melt change, and droughts and wildfires increase in frequency and intensity. Many species, including the Chinook salmon, westslope cutthroat trout, and native bull trout are at risk.

Fortunately, managers still have time to implement conservation measures with the potential to yield high future dividends. Here are three stories illustrating how climate researchers are helping.

Fighting for Chinook

Before Erika Sutherland was an aquatic ecologist, she was a fighter pilot.

“One of the rare opportunities I had was to look down on the world, all over the world, and see impacts, including how many political problems were caused by the sharing of water,” says Sutherland.

Sutherland’s aerial perspective helped her appreciate just how essential water is. Without it, not much survives, whether in human settlements or in ecological systems. Sutherland was inspired. She went on to study freshwater systems and what makes watersheds healthy.

Now a Northwest Climate Science Center (NW CSC) Graduate Fellow at the University of Washington, Sutherland has exchanged the pilot seat for a snorkel, which she uses to study rivers in the Pacific Northwest. Her current work focuses on the effects of climate-related stream warming on native salmon and helping managers strategize salmon conservation.

Climate projections indicate many salmon species will lose significant portions of their historic habitat as streams warm into ranges that the fish have not evolved to tolerate. At the same time, climate change provides an opportunity for introduced warm-water predators, such as the smallmouth bass, to expand their range into salmon rearing areas that were historically too cold for them.

In Oregon’s John Day River, where Sutherland conducts fieldwork, smallmouth bass have already

Image on the previous page: A male smallmouth bass guarding his nest in Oregon's John Day River. (Photo: ©Erika Sutherland)

expanded their range upstream, creeping into habitat critical for developing juvenile Chinook salmon. The juveniles don't recognize the bass as threats, making them easy prey for the voracious predators.

Snorkeling for hours a day over large stretches of river—a dream job for Sutherland—the researcher is studying the biological constraints keeping smallmouth bass from expanding farther into colder waters—including temperature impacts on the hatch rate of eggs and growth of their fry. Sutherland says as she learns more about the mechanisms limiting the bass's range expansion, she may be able to help curtail further invasions.

Understanding Climate Threats to Westslope Cutthroats

Farther west, in the remote upper Flathead River system of Montana and British Columbia, NW CSC and Great Northern Landscape Conservation Cooperative-funded U.S. Geological Survey biologist Clint Muhlfeld is documenting a similar story about pressures from climate change and an introduced species endangering a beloved native one.

Generations of fly-fishers have long prized the Flathead Basin for its cinematic backdrop of glacier-carved valleys and for its large, native westslope cutthroat trout, famous for their eagerness to take bait. Today, warmer air temperatures in the basin mean earlier spring run-off, lower summer flows, and warmer waters.

Native fish are losing habitat as the introduced rainbow trout expands its range. However, in this case, the threat from an introduced species is less about predation than something more amorous.

The rainbow trout are mating with the cutthroats and that's not good for the species' future survival, says Muhlfeld.

"Protecting genetic integrity and diversity of native species will be incredibly challenging when species are threatened with climate-induced invasive hybridization," says Muhlfeld.

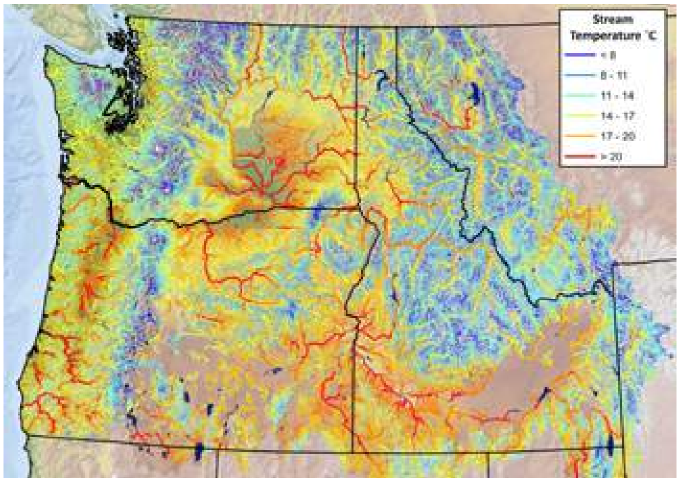
Genetically pure native westslope cutthroat trout, like these, are becoming rare as climate change increases rates of hybridization with introduced rainbow trout. (Photo: Jonny Armstrong, U.S. Geological Survey)

Erika Sutherland studies the effects of climate-related stream warming on native salmon in Oregon's John Day River. (Photo: ©Erika Sutherland)

Once hybridization occurs, says Muhlfeld, there's no way to return to genetically pure lines. According to his research, hybridization is having disastrous results for native westslope cutthroat trout. Progeny of interspecies liaisons are poorly suited to their environment, usually dying without reproducing.

Muhlfeld's study, which is based on 30 years of research, has been the first to demonstrate the potential for climate change to decrease biodiversity by fostering cross-breeding between invasive and native species, a risk that was, until now, largely theoretical. Muhlfeld published his results in *Nature Climate Change* in December 2013.

"The evolutionary consequences of climate change are one of our greatest areas of uncertainty because empirical data addressing this issue are extraordinarily rare," says Ryan Kovach, Muhlfeld's co-author on the study. "This study is a tremendous step



This colorful map shows average stream temperatures for central Idaho's Salmon River Basin from 1993–2011 as predicted by the NorWeST temperature model. More than 234,000 kilometers (145,400 miles) of streams have been computer modeled across the Northwest. To aid natural resource managers with science-based decision-making, temperature data and other products from the models are publicly available on the NorWeST website. The project's database can be accessed here.

forward in our understanding of how climate change can influence evolutionary process and ultimately species biodiversity."

Tracking Northwest Stream Temperatures

Chinook salmon and westslope cutthroats face many of the same challenges confronting a wide range of aquatic species across the Northwest. Successful management of our region's freshwater resources requires a landscape-level approach and the coordination of many diverse groups.

Currently state, federal, tribal, and non-governmental organizations throughout the region are working together, producing powerful tools to help strategize conservation efforts. One example of this productive collaboration is the NorWeST Project's stream temperature data archive.

Eight years ago, Daniel Isaak, a research fish biologist with the U.S. Forest Service, was attempting to analyze the impacts of wildfire on bull trout habitat when he realized that he needed a better temperature map.

"At the time," explains Isaak, "there were no great analytical approaches available, although there were lots of data out there on summer stream temperature, along with data on where, why, and for how long these measurements were taken."

So Isaak set about putting together a database of stream temperature records. The data he collected from multiple agencies turned out to be highly accurate and more abundant than he'd first expected.

Meanwhile the newly formed Great Northern Landscape Conservation Cooperative (GNLCC) was setting its first year priorities. Chief among them was investigating the impacts of climate change on cold-water fish species. However, as researchers at the GNLCC soon learned, one potential obstacle complicating the effort was a lack of stream temperature modeling.

Here's the problem: stream temperatures don't relate directly to air temperatures. Instead they depend on a suite of environmental factors, including snow melt, flow rates, and the stream's slope and aspect, to name a few. That means in order to better map future stream temperature projections you first need a model to relate air temperature projections to stream temperatures. For that the GNLCC turned to Isaak, funding him to expand his centralized stream temperature database and develop a computer model to better simulate stream temperatures.

Three years later, Isaak's work—which later received funding from the North Pacific LCC—yielded an empirical statistical model capable of projecting stream temperature with high (90 percent) accuracy. The model combines downscaled, air temperature projections from global climate models with 11 publicly available predictor variables (such as elevation) in order to map future climate scenarios for all streams across the Northwest region.

Likely the largest of its kind, the stream temperature database Isaak and his team compiled is impressive, encompassing measurements from more than 234,000 kilometers (145,400 miles) of streams over the course of 20,000 separate field campaigns. More than 60 state, federal, tribal, and private resource agencies have contributed from across Oregon, Washington, Idaho, Montana, and Wyoming.

The end product is a series of "pretty maps", as Isaak describes them, showing, among other things, how much habitat is left for native fish and how that habitat is likely to change over time. These maps highlight places that are big enough and likely to stay cold enough to support native fish in the future. Groups, including the Blue Mountain Adaptation Partnership and the Northern Rockies Adaptation Partnership (started by the University of Washington's David Peterson and funded by the National Oceanic and Atmospheric Administration through the Pacific Northwest Climate Impacts Research Consortium), are using the maps to prioritize conservation and restoration efforts.

Looking to the Future

Ultimately the best hope for the Northwest's native fish rests in the combined efforts of people such as Sutherland, Muhlfeld, Isaak, and the countless others across the region, monitoring, modeling, snorkeling, and planning. The good news is that the Northwest still holds places suitable as future refugia for salmon and trout, and people are acting now to mitigate climate impacts on native fish.

NWC

Maximizing Return on Investment

Smallmouth bass, much prized by anglers, were first introduced to the Northwest in the 1920s. For several decades following, the fish were managed locally to increase their numbers and range. Because they preferred warm waters, such as those in the Eastern U.S. where they originated, the bass overlapped very little with the Northwest's cold-water-loving native salmon and trout. As recently as 1985, the Washington Department of Fish and Wildlife found no evidence of population-level impacts of smallmouth bass on salmon. But what a difference 30 years can make.

A combination of reduced forest cover and rising global temperatures has warmed Northwest streams, increasing smallmouth bass population size, upstream range, and altering the species' dynamic with native species. Consequently, by the early 2000s, bass were found to be eating up to 35 percent of salmon runs in some areas.

Former Northwest Climate Science Center Graduate Fellow David Lawrence was the first to use downscaled climate data to computer model how warming streams could change the distributions of salmon and bass in the Northwest. Like Clint Muhlfeld (see main story), Lawrence was interested in the interactions of multiple stressors, including introduced species, climate change, and land use. His goal: to figure out, as he put it, "What are our options? And, given our options, how do we actually operate in the most cost-effective way to reduce the risks

David Lawrence, Director of Freshwater Fish Conservation at the National Fish and Wildlife Foundation. (Photo: ©David Lawrence)

from climate change?" Ultimately Lawrence wanted to be able to tell managers exactly where to put their limited dollars to maximize their return on investment.

Lawrence's results indicate that Chinook rearing-habitat will likely disappear completely by the end of the next century in parts of the Columbia River Basin, where grazing and other land uses have reduced stream-side vegetation. But "all is not lost," he quickly points out. Many areas are good candidates for targeted restoration. Shade from reestablished trees and shrubs along the streams could cool waters, simultaneously providing suitable habitat for Chinook and stemming the expansion of smallmouth bass.

Lawrence graduated from the University of Washington in September of 2013. He published his results in Ecological Applications in June of 2014. He now directs Freshwater Fish Conservation at the National Fish and Wildlife Foundation.

The North Pacific Landscape Conservation Cooperative

HISTORY

The North Pacific Landscape Conservation Cooperative (NPLCC) was established as one of 22 LCCs by the Department of the Interior through the signing of Secretarial Order No. 3289.

MISSION

To promote development, coordination, and dissemination of science to inform landscape-level conservation and sustainable resource management in the face of a changing climate and related stressors.

FOOTPRINT

The Pacific coastal areas of northern California, Oregon, Washington, British Columbia, and southeast Alaska.

THE North Pacific Landscape Conservation Cooperative (NPLCC) is a self-directed partnership between federal agencies, states, Tribes, First Nations, non-governmental organizations, universities, and other entities to collaboratively define science needs and jointly address broad-scale conservation issues, such as climate change.

The NPLCC combines the collective science capacity, infrastructure, creativity, perspectives, and sometimes, financial resources of existing partnerships and programs to address decision support needs on a comprehensive scale. It is a forum for developing a common understanding of change driven by climate and related stressors and its success depends on active engagement of partners throughout the region.

We currently focus on five priority topics: 1) Effects of hydrologic regime shifts on rivers, streams, and riparian corridors; 2) Effects of change in air temperature and precipitation on forests; 3) Effects of changes in sea levels and storms on marine shorelines, the nearshore, and estuaries; 4) Effects of the changes in the hydrologic regime on anadromous fish; 5) Invasive species, diseases, pests, and their effects on biological communities.

Over the past four years the NPLCC has funded or co-funded over fifty projects focused on priority topics ranging from conservation planning and design to vulnerability assessments. *For more information, visit northpacificlcc.org.*

Members of the NPLCC Steering Committee join Glynnis Nakai, refuge manager at Nisqually National Wildlife Refuge for a guided refuge tour during the Committee's semiannual in-person meeting. (Photo: John Mankowski, NPLCC)

Featured Project Partners and Contributors:

NW CLIMATE magazine

May 2015

Northwest Climate Science Center
C/O Lisa Hayward
University of Washington
Box 355674
Seattle, Washington 98195
lhayward@uw.edu

Marys Peak at Sunset. Benton County, Oregon, (©Dudley Chelton)