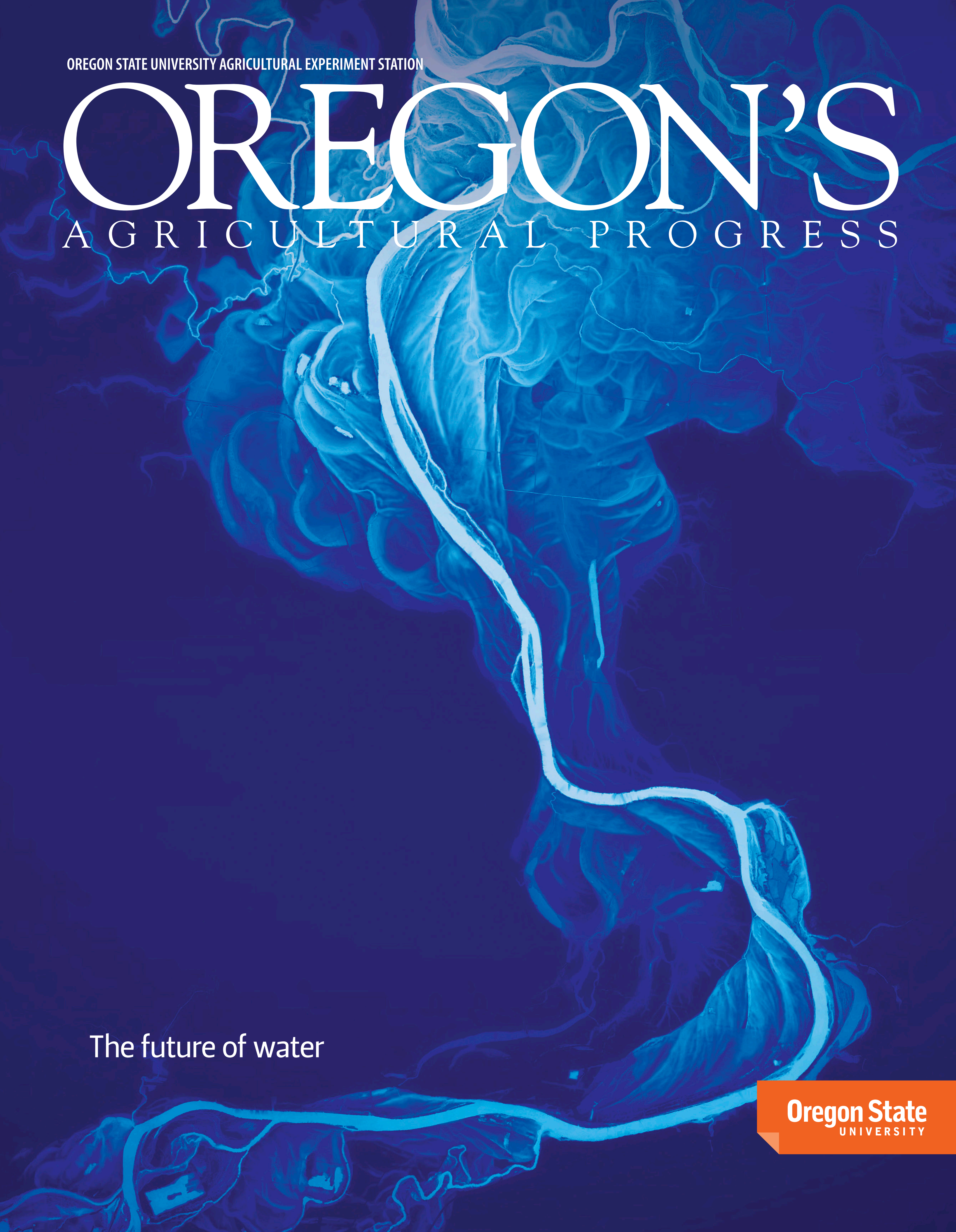
OREGON STATE UNIVERSITY AGRICULTURAL EXPERIMENT STATION

OREGON'S AGRICULTURAL PROGRESS



The future of water

Oregon State UNIVERSITY

OREGON'S AGRICULTURAL PROGRESS

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Front cover: LiDAR-derived image of the Willamette River by Daniel Coe, DOGAMI

Contents photo: Dry-farmed tomatos. Photo by Lynn Ketchum

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The future of water

What is that on our cover? A plume of smoke? Dissolving chemicals? A drift of whale poop?

In this issue of *Oregon's Agricultural Progress*, we explore the future of water in Oregon and beyond. The cover shows the Willamette Basin and its memories of channels, a LiDAR image created by Daniel Coe at Oregon's Department of Geology and Mineral Industries.

LiDAR uses pulsed lasers to remotely measure landscape features. It's just one of many new tools scientists are using to observe changes in water and climate. Scientists at OSU's College of Agricultural Sciences are not simply using these tools to document change; they are creating ways to mitigate the changes that we can control and ways to adapt to changes that we cannot control.

The stories in this issue explore new designs for protecting water quality, reducing water use, and living sustainably on this watery planet. When you think about it, our future *is* the future of water.

Peg Herring

Additional features online: **oregonprogress.oregonstate.edu**

- Introduction to the Marine Studies Initiative at OSU
- See dry-farmed produce from harvest to taste-test
- Hong Liu gives a quick tour of her lab and instruments
- *National Geographic:* Whale tagging and why it's done

Read *Oregon's Agricultural Progress* on your tablet with our new app, available at: oregonprogress.oregonstate.edu/winter-2017/apps

OAP

A changing climate **for water**

By Peg Herring

Our blue planet has a lot of water. It's the same water that's been here for billions of years. No more, no less. However, Earth's water is constantly rearranged—frozen as ice, steamed into vapor, or flowing in rivers. This rearrangement of water is probably the most obvious thing most of us can see in a changing climate. We see increasing floods and droughts, while scientists monitor decades-long trends in rising sea level and global temperatures.

"Oregon is a great place to study water and climate change because we have such varied geography and climate zones," says John Selker, an ecological engineer in OSU's College of Agricultural Sciences. "The diversity of climate zones in our state parallels the diversity of the globe: from oceans to desert, mountains to valleys, glaciers to cropland. It's possible to expand our understanding of large-scale trends by examining regional-scale trends observable in Oregon." Oregon is a model for the world.

A precipitation map illustrates Oregon's climatic diversity in shades of purple, green, and gold. Our climate is dominated by two huge forces—the atmosphere and the ocean—plus a complex topography of mountain ranges. As a result, we see large variations in temperature and precipitation in short distances west to east, across the state. Those mountain ranges capture much of the state's water. The release of that water, as runoff or snow melt, drives the migration of salmon, the growth of forests, and the availability of water to use for drinking, irrigation, recreation, and hydropower. The availability of water has shaped the state's ecosystems and economies, affecting what grows where, what's built where, and which strategies we choose to manage our water. Projected climatic changes are likely to throw a monkey wrench into many of these strategies.

Over the last 15 years, dozens of studies of changing climate have been published. Oregon State scientists have been involved in many of these studies, and their research is part of huge, global datasets that cumulatively document altered precipitation, accelerated glacier melt, extreme droughts and floods, and changes in water availability worldwide.

Precipitation in Oregon is a story painted in purple, green, and gold.

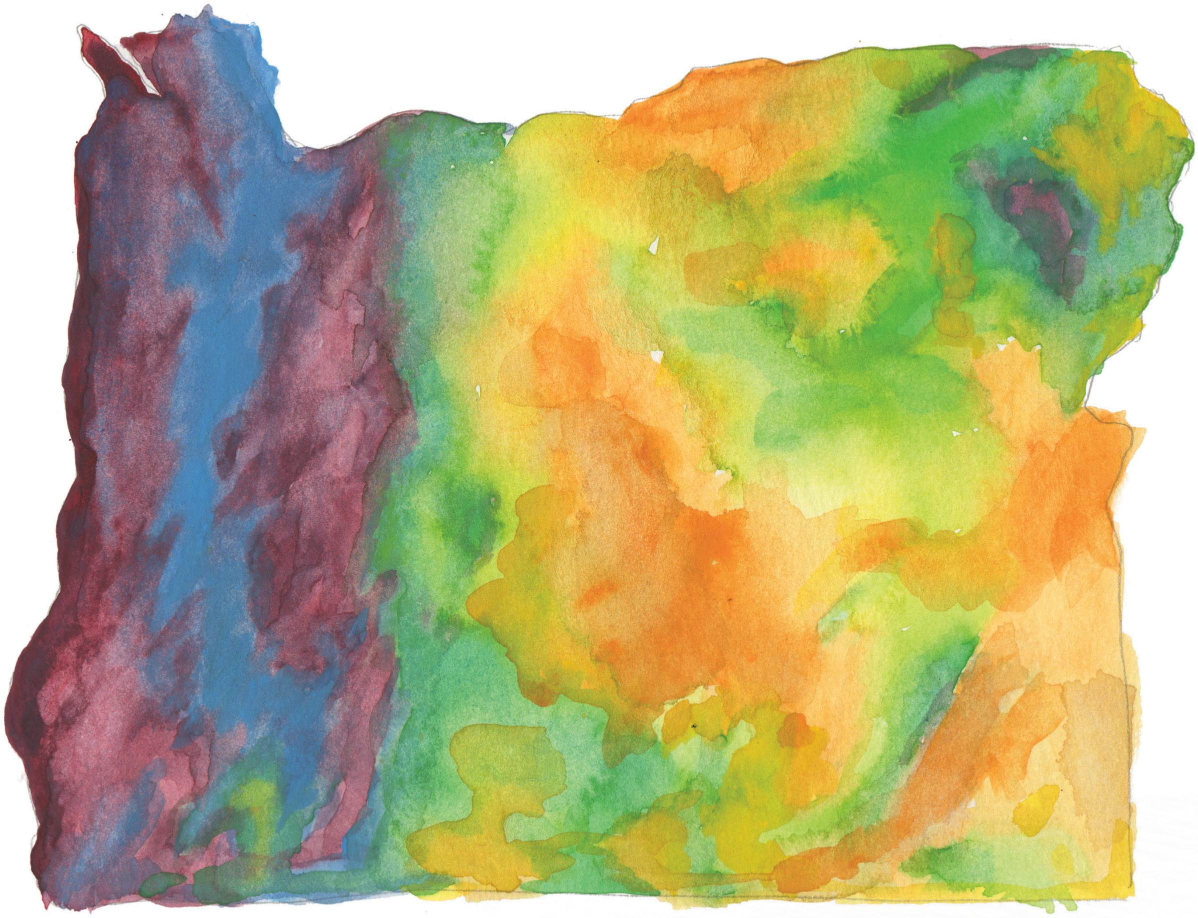
The trends are similar in all these studies. "Measurable changes, like higher heat, wilder weather, rising sea levels, are symptoms consistent with what all the climate models suggest we'll see in the future," says John Bolte, head of OSU's Department of Biological and Ecological Engineering. What can we learn from these climate models? There is no one-size-fits-all answer. Oregon's diversity, like the world's, will drive different changes in different ways.

Climate models all agree that heat extremes will increase and cold extremes will decrease. Most models predict that Oregon's total annual precipitation will remain about the same, with most precipitation falling in winter, and most of that in the mountains. Less of that precipitation will be stored as mountain snow, so stream flows will peak earlier. That could mean less water available in summer for irrigation, hydropower, and fish habitat.

Global sea level is rising, driven in part by melting glacial ice and by the fact that warmer water takes up more space. Climate studies project that sea level along the Northwest coast will rise between 4 and 56 inches by 2100, with significant local variations. As sea levels rise, saltwater will intrude farther into rivers, shrinking freshwater habitats. Ocean wave heights will likely increase, which will in turn increase coastal erosion. Coastlines battered by more frequent storms will reshape themselves, which could affect coastal highways and bridges. Across the state, municipal water supply and flood control infrastructures will be affected by increased storms and flood risk.

Long-term data show that ocean temperatures off our coast, although quite variable, are likely to increase, and ocean circulation will continue to change in response to ocean-atmospheric processes, which will affect marine ecosystems. Rising water temperatures promote earlier and longer-lasting, harmful algal blooms associated with paralytic shellfish poisoning. The climatic link to ocean acidification is unclear, but acidified waters hinder the ability of some ocean animals to build shells and skeletons. Shellfish aquaculture is particularly threatened by ocean acidification.

Oregon agriculture is already adapting to many climate changes.



Peg Hering illustration

Annual average precipitation inches/year

From USDA Natural Resources Conservation Service, 1961–1990 data

Growers are experiencing an increase in frost-free days and higher temperatures. Irrigated crops could be vulnerable as demand for available water increases and supplies decrease.

As a critical measure of snowpack, all climate studies use the amount of snow that remains in the mountains by April 1. Studies show that the April 1 snowpack will continue to decline, prompting earlier peak stream flows, warming stream temperatures, and reducing available water in summer. Salmon will experience the impacts of a changing climate throughout their lives in freshwater, coastal, and marine environments.

There is no established map into this future. When we consider what to plant, where to build, which fish to harvest, or how much water to store in reservoirs, we depend on assumptions based on our past experiences. We locate highways and plan bridges, culverts, and dams based on what we expect from past climatic conditions.

As the climate changes, we need to adjust our expectations. Our scientists are not merely documenting the changes that are upon us. They are working to reduce negative consequences and discover new opportunities that climate change will deliver. | **OAP**

This article summarizes findings from:

Climate Change 2014: Synthesis Report.

Intergovernmental Panel on Climate Change. United Nations. 2014.

Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities. Island Press. 2013.

Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. National Research Council, National Academies Press. 2012.

Willamette Water 2100 (as reported in this magazine on page 34)

Research at the **Edge of the Pacific**

Portraits of marine studies from the College of Ag Sciences

Edited by Phillip Brown

The College of Agricultural Sciences might not be the first place you'd expect to find world-class marine research. But here it is. For more than 75 years, our researchers have lived and worked on the Oregon Coast, creating opportunities for coastal communities and economies. Our scientists lead the world in understanding marine systems, from the smallest phytoplankton to the largest mammals on earth.

The following portraits highlight a few of the people who have built this distinction for the College of Agricultural Sciences. Many of our scientists who have blazed this trail are now passing the baton to the next generation of extraordinary scientists.

This portrait gallery celebrates the College's future as well as its legacy of marine research.

Marine ecologist Fiona Tomas Nash and colleagues collect invertebrates at low tide in Newport's Yaquina Bay.

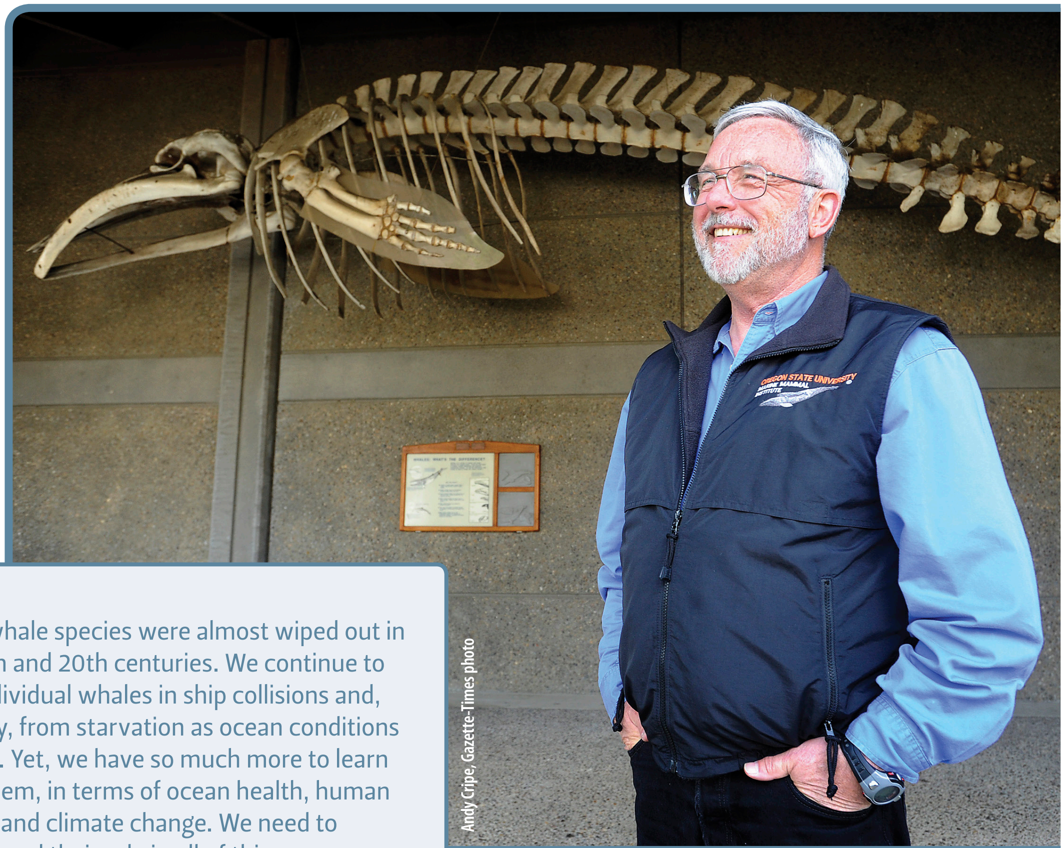

Lynn Ketchum photo

Bruce Mate

whale research pioneer

For more than 40 years, I've tracked whales in every ocean on earth. Over time, we've developed the use of satellite-monitored radio tags and sensors to measure ever more precise information about the largest animals on earth.

Our radio tags revealed where these animals migrate to feed and to breed, sending out signals over several months and thousands of miles: "beep, beep, beep, here I am!" Now, we've developed sensors that record what's happening between those beeps—second-by-second behavior of whales, including their location, dive durations, depths, and accelerations. From these data, we can track a sperm whale as it dives a mile down then suddenly lunges toward a giant squid; and we can track the sudden switch of humpback behavior from highly variable dives feeding in southeast Alaska to a steady, arrow-straight migration to Hawaii for breeding.



Andy Cripe, Gazette-Times photo

Many whale species were almost wiped out in the 19th and 20th centuries. We continue to lose individual whales in ship collisions and, recently, from starvation as ocean conditions change. Yet, we have so much more to learn from them, in terms of ocean health, human health, and climate change. We need to understand their role in all of this.

What I used to love most about this work was the thrill of being on the ocean in the presence of such magnificent animals. I gave up going to sea a few years ago due to age and "mileage." But I mentored well, and now have great people who are doing a wonderful job of what I used to love to do. Now what I love most is sharing our discoveries with other people and securing the future of the Marine Mammal Institute with the help of like-minded friends. To that end, my wife Mary Lou and I have committed $800,000 as an endowed estate gift to support graduate students at the Institute to continue this conservation-oriented work in perpetuity.

It is important work. Whales are part of the intricate clockwork of nature. You can change the size of some parts, and the system can adjust; but if you rip out a gear, the clock stops. The Marine Mammal Institute has grown into a consortium of many disciplines, with people from many places, working together to make sure that Nature's clock keeps running on time.

Bruce Mate—OSU Marine Mammal Institute (Director) and Department of Fisheries and Wildlife

Leigh Torres

marine mammal behavioral ecologist

I've always been interested in marine mammals and how they make a living in the ocean. Whales are mammals, like us, but they live in a completely different environment. It's fascinating to me, trying to figure out how they do it.

Whales are very acoustically active. They use sound to navigate, to communicate, to find food and mates. And the louder it gets in the ocean, the harder it is for them to hear and communicate. Think of what it's like to be at a rock concert. Now imagine that concert was in your kitchen. It would eventually stress you out! And the more stress that you're under, the more your immune system can be compromised. The same is true for whales.

Ocean noise has been rising for the past several decades, mostly due to huge shipping tankers crossing the oceans, seismic survey exploration, and Navy sonar. And as more and faster ships are introduced, that noise will continue to increase, as well as other impacts on the marine environment, which could affect whales in a multitude of ways.

Currently, we're studying the foraging behavior of gray whales—how they forage, where they forage, and how different human impacts like ocean noise, vessel activity, or fishing gear might impact their behavior and health. By understanding whales' normal behavior and stress levels, we can recognize how these human impacts are affecting the whales and where it might be critical to implement management strategies. Every day we go out on the ocean, we see something new or learn something new about these animals.

> Using a drone has given us a new perspective on whale behavior that we couldn't get from our traditional, horizontal view from a boat. Now that we can fly above them and look down through the water column, we're seeing more of what the whales are doing underwater.

Leigh Torres—OSU Marine Mammal Institute, Sea Grant Extension, and Department of Fisheries and Wildlife

Stephen Ward photo


Stephen Ward photo

Steven Dundas

coastal environmental economist

We put incredible pressure on our coasts through development and food production. Nearly 40 percent of the U.S. population resides in coastal counties, and many commercial operations are dependent on coastal and marine environments. To preserve coastal ecosystems, we need to understand the full benefits and costs of our actions.

For example, we know the basic costs of "gray" infrastructure, such as riprap and seawalls, to provide certain levels of flood and storm protection. What if we change our thinking and invest in "green" infrastructure through the restoration of dunes and salt marshes? Such natural infrastructure can provide similar levels of protection and also offer benefits from other ecosystem services that habitat restoration provides.

As an economist, I study public demand for these kinds of environmental goods and services. Through a transdisciplinary NOAA grant, my colleagues and I are using the Oregon Coast as our laboratory, specifically looking at green infrastructure investments in four areas of concern: coastal protection, estuary habitat restoration, dune habitat restoration, and land-use in acute hazard zones (think: tsunami). We quantify the value of environmental changes using tools, such as discrete choice surveys, that elicit what people would be willing to pay for these green infrastructure investments.

> We rely heavily on our coastal environments for a variety of things—where we get our food, where we live, where we recreate. Beginning to understand the value of those services is a first step in designing policies that balance our economic needs and environmental concerns.

Understanding public preferences for coastal ecosystem services in the Pacific Northwest will help us inform policy makers and stakeholders to determine where, when, and how to best invest in natural infrastructure. Communicating our research is key. And if government officials and legislators are interested in our work, I am doing my job.

Steven Dundas—Coastal Oregon Marine Experiment Station and OSU Department of Applied Economics

Gil Sylvia

director of Coastal Oregon Marine Experiment Station

I enjoy bringing people together—fishermen, faculty, students, and staff—to address tough problems and awesome opportunities. As director of COMES, I help lead this group of people, together with an advisory board made up of members of industry and the public, in addressing two vital questions—how can we get greater value out of using marine resources, and how do we conserve those resources over time in smart, rational ways? The vital mission of COMES is to integrate the concepts of use and conservation in ways that truly align with the principle of sustainability.

Right now, our faculty are working on over 50 projects. Many of these projects are in collaboration with faculty from other colleges and with members of the fishing and seafood industry, people working and living in our coastal communities. Such a transdisciplinary approach is consistent with goals of the Marine Studies Initiative. Translating work into action that creates value for the people of Oregon—that's what I find most exciting.

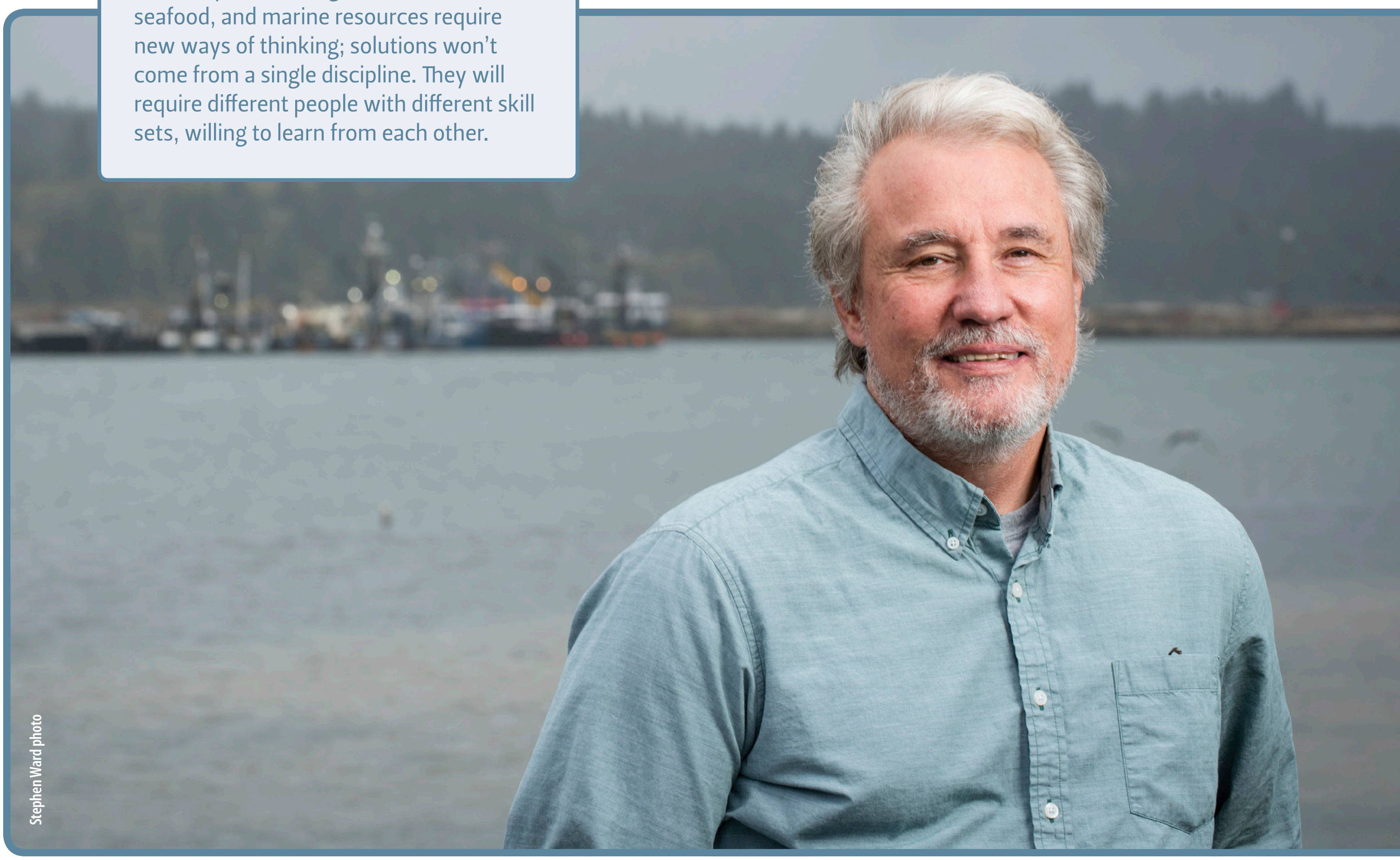
Oregon State has amazing abilities to look at ecosystems with a broad biological and sustainable management perspective, and to take a whole food systems perspective. Those two perspectives have led to a new strategic concept called "Food from the Sea."

OSU has all the elements needed to address the full range of opportunities and issues in the concept of "Food from the Sea" and create something unique worldwide. We have the Hatfield Marine Science Center, the Coastal Oregon Marine Experiment Station, the Astoria Seafood Laboratory, and the Food Innovation Center in Portland. And we have partners on campus and collaborators in the fishing, seafood, and processing industries, as well as chefs, restaurateurs, and retailers.

I like the idea of working collaboratively to get the best ideas on the table, and then pulling teams together to actually put those ideas into action.

Gil Sylvia—Coastal Oregon Marine Experiment Station (Director) and OSU Department of Applied Economics

> The complex challenges in fisheries, seafood, and marine resources require new ways of thinking; solutions won't come from a single discipline. They will require different people with different skill sets, willing to learn from each other.



Stephen Ward photo

Stephen Ward photo

Scott Baker
cetacean geneticist

Exploitation of whales has a long history—over 1,000 years of commercial whaling—and I think we're moving from that period of exploitation to a stewardship of these populations. Whale populations are recovering, so their role in the ecosystem is likely to change. How we relate to recovering populations, and how they relate to other marine resources (some of which are in demand by humans, some of which are not) is going to be one of the great challenges of the next few decades.

> There will certainly be pressure from some nations to return to whaling. It's difficult to predict how this might be resolved. I'd like to think that any return to commercial exploitation would not repeat the tragic mistakes of the past. Certainly, science has informed us about those mistakes and can help us correct them.

I'm broadly interested in life history, population dynamics, and conservation genetics of whales and dolphins. Some of my work involves surveys of markets selling whale meat in Japan and Korea, using molecular methods to identify species, particularly protected species.

Fortunately for me, I'm also involved in studies of living dolphins and whales. My work has tended to focus on populations that either were under threat in the past or are under threat today, using genetic tools to estimate both abundance and the difference among populations. As a result of some of that research, there has been a major review of the status of humpback whales worldwide.

We no longer think of humpback whales as a single population worldwide or even within a particular ocean. In fact, distinct populations of whales within oceans differ in their abundance, threats, and history of exploitation. Some populations of humpback whales have shown evidence of strong recovery and will now no longer be considered endangered. This allows us to direct our attention to those that have not shown evidence of recovery.

Interacting with living whales and dolphins in their natural environment is one of the great experiences of my life. We share with them so much of our mammalian heritage, but what makes them special, what makes them truly awe inspiring, is their remarkable evolutionary adaptation to the marine environment.

Scott Baker—OSU Marine Mammal Institute (associate director) and Department of Fisheries and Wildlife

Stephen Ward photo

> Ultimately, it's a question of conservation and management. We have to conserve the marine system, as well as the populations that live within it, particularly if we want to be able to harvest them for food.

Jessica Miller
fisheries ecologist

A fish's life history encompasses all the ways a fish makes a living, including everything it needs to complete its life cycle. We look at how current environmental variability and potential future changes in the ocean could affect how fish grow, how they feed, how they move, and how they survive to reproduce. Without putting all these pieces together, we can't really understand how the environment is affecting the relative abundance of fish populations.

Most of my research focuses on understanding patterns of life-history variation in salmon and marine fish and how that life-history variation affects our ability to conserve and manage these fish. By considering the entire life history, we can begin to understand why some populations do well in some years and not so well in other years, how various populations are connected, and how individual fish disperse and move around the ocean.

One simple tool I use is a light trap, which catches small marine organisms, like fish larvae, that are attracted to light. At night, they enter through the funnels, and then I collect them early in the morning. What I find helps me investigate questions about early life stages, future quantities, and the significance of various oceanographic factors.

The research is particularly relevant because many populations of Pacific salmon are listed under the Endangered Species Act. If we have a solid understanding of the factors that influence their survival, we can do a good job of managing and maintaining them, so they will be able to support recreational and commercial fisheries into the future.

One of the things I enjoy most about being an academic researcher is that I participate in all aspects of the research. I had several jobs in the past where I completed small parts of a research project or participated in only certain steps. With my position at OSU, I have the opportunity to think through the problems and questions and formulate hypotheses and ways to test them. I also work with students and other collaborators in the field and in the lab. I really do enjoy participating in all parts of the process.

Jessica Miller—Coastal Oregon Marine Experiment Station and OSU Department of Fisheries and Wildlife

Jason Graff

marine phytoplankton researcher

The phytoplankton bloom in the North Atlantic Ocean is similar to the springtime greening of trees on land, with concentrations of microalgae peaking in April or May. Some phytoplankton blooms are so dense that if you compared a glass of seawater from winter to one from late spring, you could see the difference in color with your naked eye. Even when the difference isn't visible by looking, we can quantify those changes with samples collected at sea or from remote platforms like satellites.

Our current project (NASA's North Atlantic Aerosol and Marine Ecosystem Study) is focused on understanding what drives this greening of the North Atlantic Ocean every spring. We make biological, physical, and chemical measurements at sea over multiple seasons, not only to observe bloom dynamics, but also to understand how the ocean and atmosphere interact.

Historically in oceanography, we have relied on chlorophyll measurements to make approximations of phytoplankton carbon or biomass. Knowing the true carbon content of phytoplankton, however, gives us a better understanding of ecosystem dynamics. With our advanced technology, we are now able to isolate phytoplankton cells from seawater and directly measure their carbon content.

When I began studying marine phytoplankton and bacteria, my interest was to make the invisible visible—to visualize and quantify cellular interactions at the microscopic level. Now, I have expanded my investigation to include plankton dynamics on annual and global scales. Using new technologies and data analysis, we can investigate phytoplankton processes to better understand and visualize how these microscopic organisms interact with their ocean environment and the overlying atmosphere.

Jason Graff—OSU Department of Botany and Plant Pathology

> If we can understand how the annual cycle of the phytoplankton works in the ocean now, it will help us understand how it might change or look different in a future ocean.

Stephen Ward photo

Scarlett Arbuckle

experiential learning coordinator and instructor

Most of my work flows through a student group called the Marine Team. It's a collaborative, interdisciplinary, interdepartmental group focused on ensuring that our students are absolutely prepared going into the job market. The reality is that employers are expecting more and more, and we want to make sure that our students get the most hands-on, real-world experiences in the marine field.

> A lot of educational experiences have to happen outside of a classroom. We talk a lot about the importance of transformative, experiential learning, but it can't happen without opportunities like the Marine Team.

Our program is very focused on engaging with the community. For example, we are doing a multi-year project where we collect specimens from charter fishing boats. After the charter crew has filleted the fish for the customer, our students get the leftover fish carcasses for further dissection. They extract the otoliths (ear bones) to learn life history, take out small pieces of muscle tissue for lipid analysis, and remove the gonads to determine the fish's reproductive stage. But instead of doing all that back in the laboratory, our students dissect the carcasses right on the dock, right next to the charter boat that caught the fish, with people coming up and asking, "What are you doing?" Students learn to explain their work in the context of this whole other, real-world community. They learn that they really need to communicate their science if it's going to have an impact.

As the students have this opportunity to work among the fishermen and onlookers, they learn skills that they will incorporate into a bigger project. I think it's really important for students to feel like they are a part of something bigger, that their science has an impact.

I love working with the students! I often carpool with them, back and forth to the coast, which gives me a chance just to talk with them. It's mentorship on the road. I love seeing students come out of their shells as they develop a little more confidence. Getting to witness the process—to follow students over time—is really rewarding.

Scarlett Arbuckle (right)—OSU Department of Fisheries and Wildlife

| **OAP**

Stephen Ward photo

THE DIGITAL FARM OF THE [VERY NEAR] FUTURE

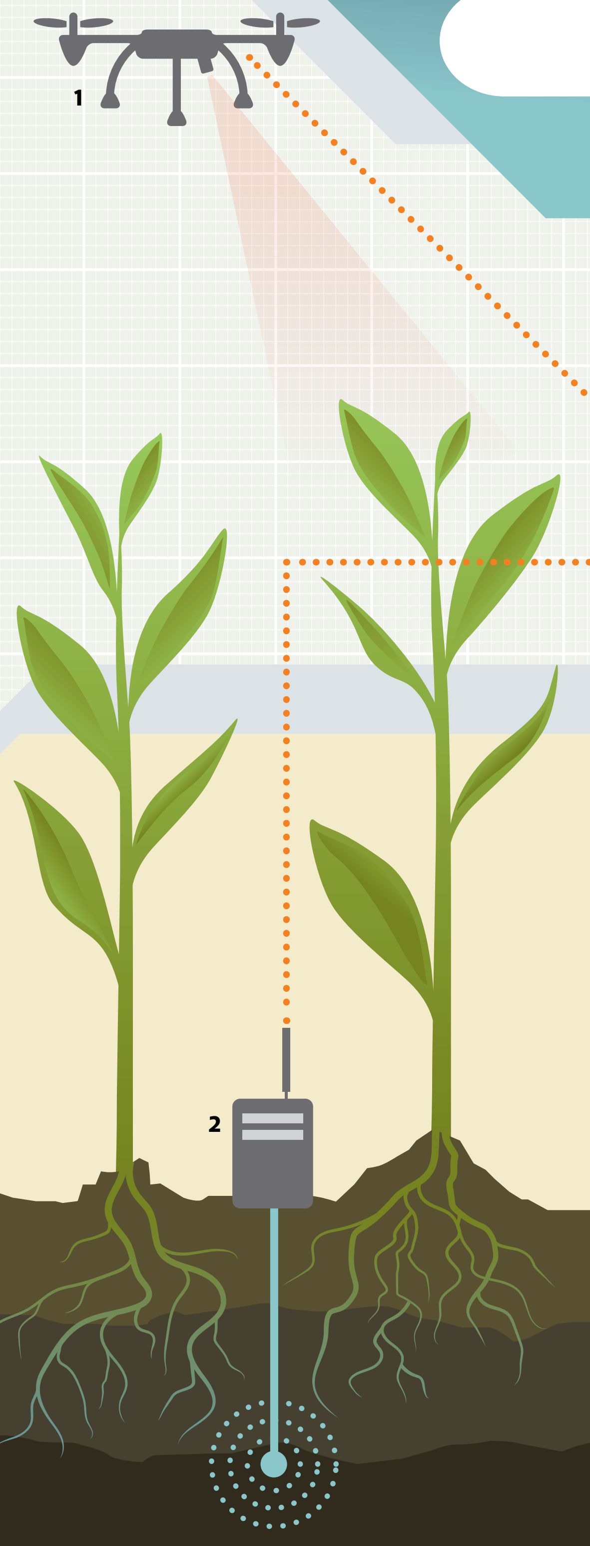
ILLUSTRATION BY ERIK SIMMONS

New technologies make it possible to collect continuous streams of environmental data. Scientists are helping farmers apply these new tools to manage soil, water, and crops in ever-changing weather and climate.

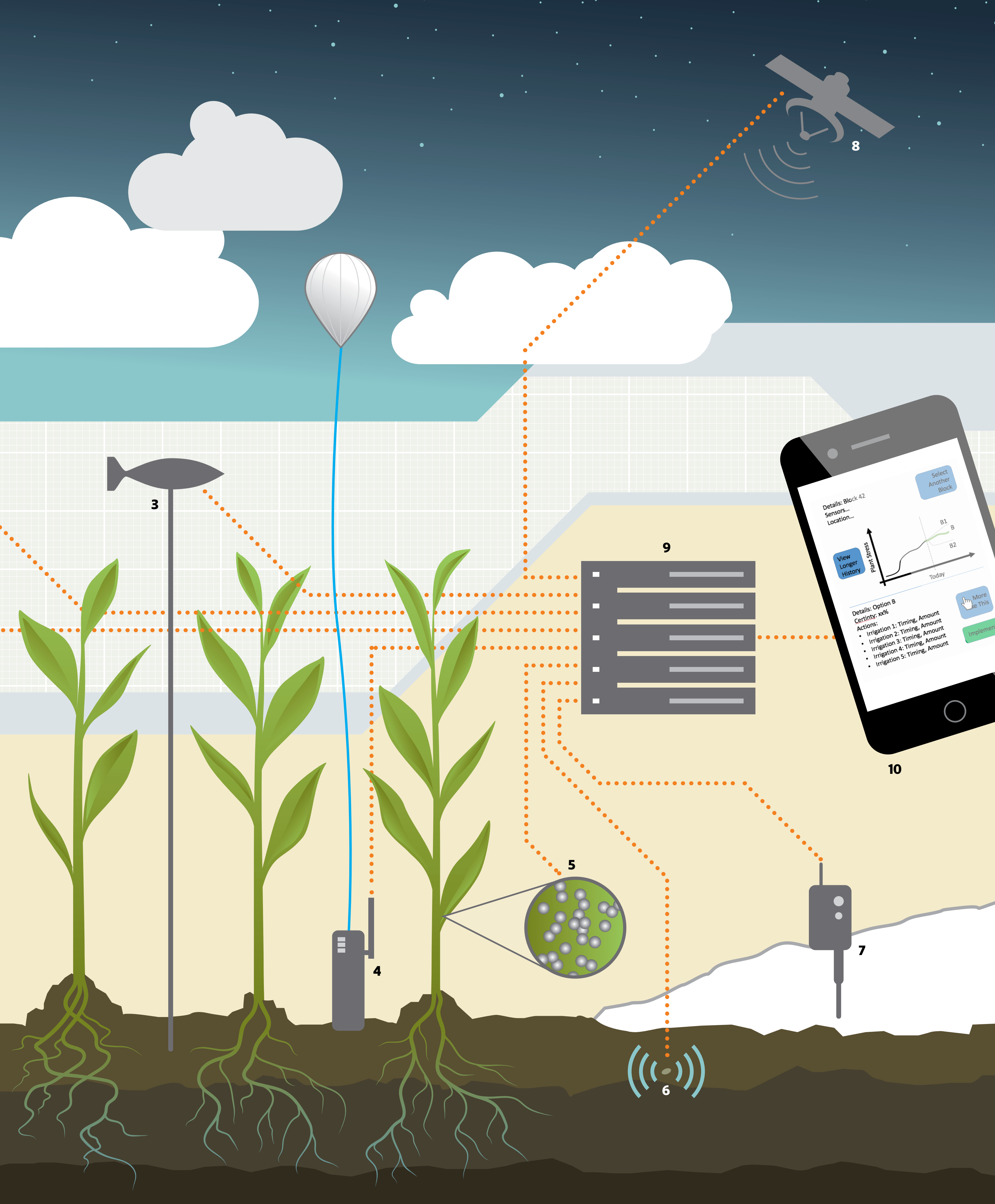
The digital farm of the future uses all kinds of sensors—drones, fiber-optic cables, radio-frequencies—to collect all kinds of sensory information. But what does a farmer do with all this information? Chad Higgins, an environmental engineer at Oregon State, helps make sense of sensory data. "We turn mountains of data into pearls of wisdom," he says.

Higgins heads the NEWAg Lab (Nexus of Energy, Water, and Agriculture) in OSU's Department of Biological and Ecological Engineering, a laboratory for precision agriculture. "New sensors make it possible to measure more things than the human brain can comprehend. We need new ways to process this information to sort out what is important," Higgins says.

In the digital farm of the future, sensory data are streamed into models that compare incoming information over time to offer a picture of environmental conditions as they change, over hours, days, or years. Computerized adaptive neural networks help farmers make the best decisions possible, with the best data available, adapted to specific in-field conditions...delivered to your smart phone.



1. **Unmanned aerial vehicles** carry cameras and recorders that pick up signals from sensors in the field
2. **Soil moisture sensors** and rain gauges help validate effective vegetative filter strips along highways, among other things
3. **Wind sensors** help unravel the dynamics of local micrometeorology that occur at the boundary of land and atmosphere
4. **Fiber optic cables** record highly precise distributed air temperature readings close to the ground
5. **Fluorescent microspheres** scanned with lasers reveal pathogen transport between plants
6. **Radio frequency identification** traces individual units of agricultural crops from field to market for improved food safety
7. **Pressure sensors** in snowpack reveal fluctuations that drive melting and sublimation of snow
8. **Satellites** measure many things, including evaporation from irrigated fields
9. **Adaptive neural networks** interpret large amounts of complex data from sensors. A form of artificial intelligence, they evaluate incoming data and make network adjustments based on continuous learning.
10. **Smart phones** present a summary of the current scenarios to the farm manager, with three potential management strategies, along with near-term and long-term impacts of the strategy.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Taking the pulse of water in western juniper woodlands

Rangeland hydrologist Carlos Ochoa places a temperature sensor in a stream near Dufur, where he is evaluating stream temperatures related to land use in dryland riparian ecosystems.

Lynn Ketchum photo

Western juniper, an iconic tree in the arid West, was once mostly confined to rocky ridges and isolated patches of shallow soil. Since the 1880s, however, it has increased its range tenfold in central and eastern Oregon, elbowing out native sagebrush and grasses and sucking up more than its share of water.

In many places where encroaching junipers have formed dense stands, bare soil is all that lies beneath the trees. Ranchers have witnessed springs drying up as junipers became abundant in a watershed. And, almost miraculously, when the junipers are cut, the water returns.

The issue of juniper encroachment is complicated; plants are just one of many interacting factors that influence how water moves across the surface and underground. In an effort to understand the impact of junipers on the water cycle, OSU scientists helped establish the Camp Creek Paired Watershed Study in the Crooked River watershed southeast of Prineville. Begun in 1993, the researchers monitored groundwater levels and stream flow in two neighboring watersheds with similar physical characteristics and vegetation. After collecting 12 years of pre-treatment data, in 2005 all except the oldest junipers were cut from one basin, leaving the other basin intact. Within months, the researchers measured an increase in groundwater and spring flow in the cutover basin.

But the research didn't end there. Now, almost 12 years after cutting, the researchers have wired the two watersheds, and the valley between them, with instrumentation including soil moisture probes, transpiration sensors, weather stations, flumes, and groundwater wells to take the pulse of hydrologic changes.

"The effects of juniper removal results in a redistribution of water budget components, largely due to the lack of tree canopy interception," said Carlos Ochoa, an OSU rangeland hydrologist whose research determined that up to 70 percent of rainfall is intercepted by the juniper canopy and never reaches the ground.

Along with Tim Deboodt, an OSU Extension rangeland specialist, Ochoa has confirmed that the cutover watershed has increased water flowing in streams and springs. They also found that soil moisture and shallow groundwater remain longer in the cutover basin, nurturing greater perennial grass cover.

"Connections between upland water sources, groundwater, and downstream valleys make a big difference to ecosystem services, including water quality and quantity, far downstream," Ochoa said.

Currently, the researchers are developing best management practices for juniper control and evaluating its socioeconomic benefits. | **OAP**

The spillover effect of dams on salmon

Christina Murphy is not chasing rainbows. She is exploring how best to manage dams to protect salmon.

The majority of Pacific Northwest hydropower dams are located on rivers that support threatened and endangered salmon. These dams are managed for power generation and flood control, and they form large reservoirs with physical and chemical properties that are different from the free-flowing rivers they displace.

Murphy is using data collected from several reservoirs in the Willamette Basin—both before and after hydrologic changes—and models of reservoir ecology to explore how changes in water levels in the reservoirs may affect food webs, water quality, and salmon growth and survival.

A doctoral student in fisheries and wildlife at Oregon State, Murphy received a prestigious STAR fellowship from the U.S. Environmental Protection Agency. The fellowship program, Science to Achieve Results, suggests that Murphy's research could have important, real-world application to management of hydropower dams in the Northwest and beyond.

"The Pacific Northwest relies on hydropower for more than half of its electricity," Murphy said. "Improved understanding of how water-level fluctuations affect the ecological mechanisms of these reservoirs is critical to ensure ecologically sound practices for the long-term operation and greening of our hydropower infrastructure." | **OAP**

photo courtesy of Christina Murphy

Christina Murphy, a graduate student in Ag Sci's Fisheries and Wildlife department, examines reservoir levels and their effect on salmon growth and survival.

INNOVATIONS in DRYLAND FARMING

By Kym Pokorny | Photos by Lynn Ketchum

The idea of growing watermelons without a drop of water is hard to imagine. But that's what is happening in western Oregon, where dry-farmed melons, tomatoes, and squash are surpassing irrigated crops in quality and taste. In uber-dry eastern Oregon, wheat has long been grown without additional water, and now a new technique is building soil moisture where every drop counts.

Melons grown at OSU's Oak Creek Center for Urban Horticulture demonstrate the possibilities of farming without adding water.

Westside story

The tasters were skeptical. They made their way past rows of ripe vegetables back to a table where plates of cut tomatoes lay ready to sample. The tomatoes looked luscious, as tomatoes do in August. But these tomatoes were grown without irrigation. The taste-testers picked up toothpicks, speared the wedges, and bit into the tomatoes. Astonishment lit their faces.

The 'Big Beef' and 'Early Girl' tomatoes grown with no irrigation tasted sweeter, had a firmer texture and deeper color than the same varieties grown with water. "You know when you cut open a fresh tomato and all the guts run out? With these, the guts stay inside, firm and contained," reported one surprised taster. "But the real difference is how they taste."

Above: Tomatoes grown successfully without water at OSU's Oak Creek Center for Urban Horticulture show promise for small farmers.
Left: Unconvinced tasters who lined up to try dry-farmed tomatoes became believers after finding them to be tastier than tomatoes grown with water.

Amy Garrett was too busy to notice. Surrounded by farmers, gardeners, and academics who had never before tasted dry-farmed tomatoes, she fielded questions until her voice rasped from the effort. "The most common question is, 'How many times did you water,'" says Garrett, an assistant professor of practice in OSU's Extension Service. "When I repeat, again, that I didn't add any water at all, they have a hard time getting their head around it."

Garrett's Dry Farming Project fascinated the 100 or so people who came to taste the results and satisfy their curiosity about an ages-old but little-used practice that, inconceivably, produced better-tasting vegetables. Earlier in the summer, Garrett had started a 4,000-square-foot trial plot of tomatoes, melons, squash, and potatoes at the Oak Creek Center for

Urban Horticulture, at the edge of OSU's Corvallis campus. She planted two rows of each vegetable variety: one row was irrigated, one was not.

The dry-farmed plants didn't go thirsty, though. As Garrett planted into the Woodburn silt loam, she compressed the soil surrounding seeds and transplants to start capillary action, lifting soil moisture to the surface to germinate seeds and encourage roots. As the season wore on, vegetable roots stretched deep, tomatoes rooted down 5 feet to harvest the receding water. She kept a thin portion of topsoil fluffed up with shallow tilling as a dust mulch to keep moisture from escaping during the dry summer days.

> "You know when you cut open a fresh tomato and all the guts run out? With these, the guts stay inside, firm and contained.

The droughts in 2014 and '15 rattled farmers in Oregon. Wells ran dry and some farmers found themselves without water early in the season. Curious about the possibility of farming without irrigation, Garrett met with Dick Wadsworth, a retired farmer in Veneta, Oregon, who had adapted California techniques of dryland vegetable farming to Willamette Valley soils. Inspired by what she learned from Wadsworth and early adopters in California, Garrett planted a demonstration plot at Oak Creek in 2015. The results were so encouraging, she launched a research-based project in 2016 to determine the quality and economic viability of dry farming for small farmers in the Willamette Valley.

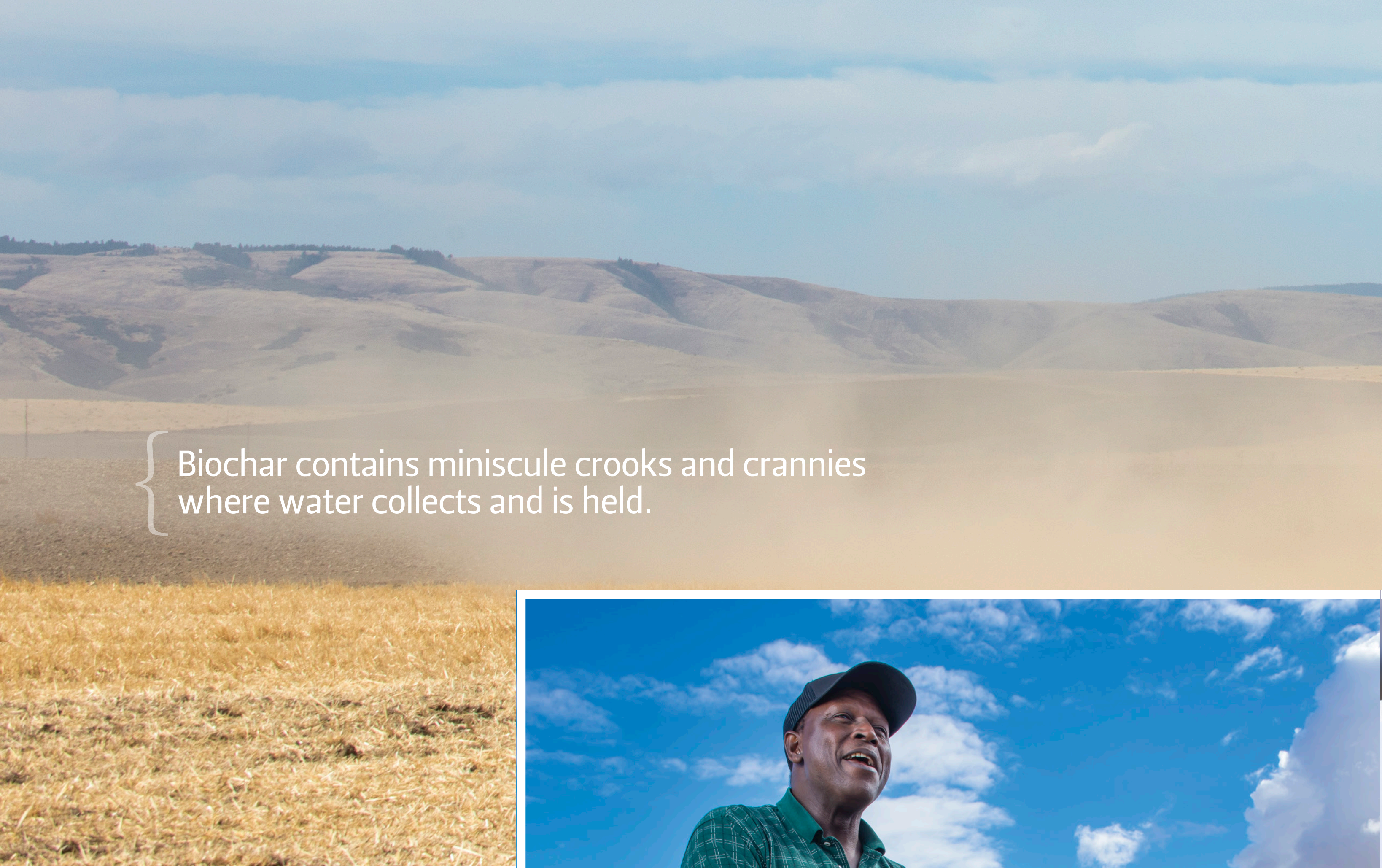
Garrett wants to know if dry farming will ease farmers' increasing anxiety about climate change and its effect on water availability. When she read the predictions made by Willamette Water 2100 (see story on page 34), her resolve strengthened. She recruited Extension colleagues Heidi Noordijk, an education program assistant at North Willamette Research and Extension Center, and Dana Kristal, Small Farms program coordinator at the Southern Oregon Research and Extension Center, to start their own trials. They followed Garrett's lead, planting well-known varieties side by side, early in the season when the most soil moisture is available for plants.

Noordijk and Kristal hosted dry farming events in their regions, and as expected, evaluations by tasters showed the dry-farmed crops have superior flavor, an important consideration to Oregon's small farmers who sell directly to the public.

The economic benefits are less clear, Garrett says. Some vegetables, such as tomatoes, produce smaller fruit when dry farmed, but richer flavor. Overall yield is lower, because non-irrigated plants are planted further apart to reduce competition for available moisture. And dry farming isn't suitable for all soils; deep, organic-rich soils with some clay content have more water-holding capacity and lend themselves to dry farming. Shallow or sandy soils are not ideal.

But considering that irrigation consumes as much as 70 percent of the world's freshwater withdrawals, dryland farming in western Oregon may be a sustainable alternative. To learn more, Garrett will continue to gather data from OSU trial plots in coming seasons, and from the new Dry Farming Collaborative, which includes many small-scale farmers who have signed on to share results. "We need to be proactive about expanding our drought mitigation toolbox," she says. "Our work is essential for future generations."

Top: Just like tomatoes, dry-farmed melons got the thumbs up from tasters. OSU trial plots in three locations had similar results.
Above: At field days in Corvallis and Aurora, tasters evaluated melons and tomatoes planted side by side: one row got water, the other did not. Dry-farmed fruit consistently got higher marks for flavor, texture, and color.



Biochar contains miniscule crooks and crannies where water collects and is held.

Eastside story

Wind blows through the wheat fields stretching out to the foot of the Blue Mountains east of Pendleton. With it comes dust, a constant reminder that some of the world's most productive soils are being swept away.

Stephen Machado nods through blowing topsoil dust. "Once it's gone, it's gone," he says. Since the 1800s when farmers first put plow to soil in Eastern Oregon, up to 60 percent of the soil's organic matter essential for retaining water has been lost. In a drought-prone region where a majority of fields are not irrigated, that's a nail-biting situation. For 16 years, Machado, an Oregon State University dryland cropping agronomist, has been researching ways to keep farming sustainable by building up soil organic matter, which he likens to currency. Without it, the underground economy starts to fail.

Machado shoves a soil probe into the bone-dry soil of August as he talks

Above: Oregon wheat, most from the dry Columbia Basin, is valued at more than $217 million annually.
Inset: Researchers are applying biochar to crop fields to boost moisture-holding capacity.
Left: Stephen Machado, an agronomist at OSU's Columbia Basin Agricultural Research Center in Pendleton, says soil is the basis of agricultural production.

about the problems of farming in a region where 16 inches of rain is a luxury. During cropping years, wheat residue—chaff, stubble, roots—adds organic matter. But as soil microbes whittle it away, residue disappears. With none to replace it the following year, supplies drift into the deficit column.

When soil lies bare during fallow years, wind and rain lift it and wash it away. No-till farming, which has become a more common practice in Eastern Oregon, helps by leaving a protective layer of plant debris on the surface. Farmers disturb the soil only once, when crops are seeded with tools designed to drill seed and fertilizer into fields at the same time. But it's not enough, according to Machado, to build organic matter in the soil.

Back in his office, Machado picks up a jar of what looks like crushed charcoal, shakes it and says, "I believe this is going to help." The coal-black material is biochar, a soil amendment made by burning plant waste slowly, at high temperatures with no oxygen, a process called pyrolysis. Biochar is being touted as a carbon-negative technology that has some promise in combatting climate change. The process traps CO_2 that trees and other plants have absorbed from the atmosphere. In nature, this CO_2 would make its way back into the atmosphere as the plant decays or burns with oxygen. With pyrolysis, the CO_2 is captured and prevented from re-entering the atmosphere. The carbon is locked in biochar, which it can continue to sequester for decades.

Biochar contains miniscule crooks and crannies where water collects and microbes hole up and gnaw on plant residue, releasing nutrients. Researchers, including Machado, have found that one application of less than 10 tons per acre—one percent by volume—is all that's needed to adequately increase water- and nutrient-holding capacity and increase crop yields. The additional moisture in the soil may allow farmers to plant every year, which boosts organic matter and crop yield.

Biochar has drawbacks. Because of limited supply, the price is steep, but higher yields could eventually offset expense. Machado tells farmers to think of biochar as a capital investment "like buying a tractor, only one that could last forever." | OAP

Technology transfer brews beer and energy

Making beer takes water. Lots of water. And the water that doesn't end up as part of the brew ends up as a slurry of leftover malted grains and yeast. That can mean high clean-up costs, as well as wasted water. To Hong Liu, it means energy.

Liu has developed a microbial fuel cell that can help brewers reduce water use and produce electricity by processing wastewater. And it's not just brewers who are interested in this new technology.

Liu, a professor in OSU's Department of Biological and Ecological Engineering, has developed an improved technology that harnesses the power of microbes to produce electricity directly from wastewater. The technology could create waste treatment plants that power themselves.

Liu's work with microbial fuel cells has been powered by state and federal grants that connect basic science and commercialization of innovative ideas. Support from the National Science Foundation and Oregon BEST, the agency that promotes the state's cleantech industry, led to Liu's founding the start-up company Waste2Watergy, with Yanzhen Fan, a previous fellow OSU researcher.

Microbial fuel cells could provide an efficient, low-cost way of treating wastewater while providing off-the-grid communities with electricity for lights or charging cell phones.

Hong Liu, a professor in Ag Sci's Biological and Ecological Engineering department, harnesses the power of microbes to produce electricity from wastewater, a technology she's testing with the brewing industry.

Stephen Ward photo

A project with Widmer Brothers Brewing is the first pilot-test of their new technology. "We chose to partner with Widmer because they are very engaged in sustainability efforts, their wastewater has an ideal mix of organic materials for our technology, and they are very interested in reducing wastewater costs," Liu said. Waste2Watergy has installed a 1-cubic meter fuel cell at Widmer's Portland brewery to treat about 1,000 gallons a day while generating electricity at the same time.

These new developments in fuel cell technology could save food and beverage companies millions of dollars in water treatment costs. Liu's aspirations for Waste2Watergy reach even farther, to developing nations where access to electricity and sewage treatment is lacking. Microbial fuel cells could provide an efficient, low-cost way of treating wastewater while providing off-the-grid communities with electricity for lights or charging cell phones.

Microbial fuel cells use microbes to oxidize organic matter in wastewater, which in turn produces electrons. These electrons flow from the fuel cell's anode to its cathode, creating an electrical current. Liu's new microbial fuel cell has reduced the anode-cathode spacing and uses proprietary separator and electrode materials to increase the amount of energy produced from the organic matter. As a result, the new fuel cell—using organic matter from grass straw, animal waste, or byproducts from food and beverage industries—produces electricity more efficiently than do anaerobic digesters and treats wastewater more effectively.

"If this technology works on a commercial scale, the treatment of wastewater could be a huge energy producer, not a huge energy consumer," Liu said. | **OAP**

Klamath trout journey toward the future

In the Klamath Basin, we can study the future, here and now. And that's exactly what Jonny Armstrong is doing, as he tracks the movements of Klamath's legendary redband trout as they navigate through a remarkably transformed basin.

Trout are cold-water fish, related to salmon. Klamath Lake in the summer—with low dissolved oxygen, high alkalinity, and temperatures approaching 80 degrees—would seem to be an unlikely place to find redbands, which are among the world's largest rainbow trout. "These trout are living in a system now that resembles conditions that might be more common in the future, with climate change," Armstrong said.

Armstrong is tracking these remarkable trout (some are up to 28 inches long) to see where they go and how they cope with the challenges of living in this huge, shallow lake, cut off from the sea. As a new assistant professor in the College of Agricultural Sciences, Armstrong is in his first year of research, working with collaborators in the Oregon Department of Fish and Wildlife. His previous research was in Alaska, where sea-run salmon are ubiquitous in cold, clear rivers. Redband trout in the Upper Klamath Basin grow as big as their sea-run cousins, but how?

"In the future, much more of our state could look like the Klamath, with river stretches that are completely unusable for fish during parts of the year."

Tagging trout in late spring, Armstrong's team has mapped fish moving across the lake and up into crystal-clear streams on the shoulders of the Crater Lake volcano. There they remained until early autumn. "These fish take a summer vacation," Armstrong said, "but they need to work the the rest of the year to pay for that vacation." It appears that redband trout feed voraciously in the lake in spring and fall, growing fast and putting on the fat they will need to survive on a much leaner summertime diet in the tributaries.

"In the future, much more of our state could look like the Klamath, with river stretches that are completely unusable for fish during parts of the year," Armstrong said. "To survive, fish will need to be migratory. And the basins in which they live will need to have cold-water refugia where fish can escape summer heat, as well as highly productive areas where fish can fatten up during the spring and fall."

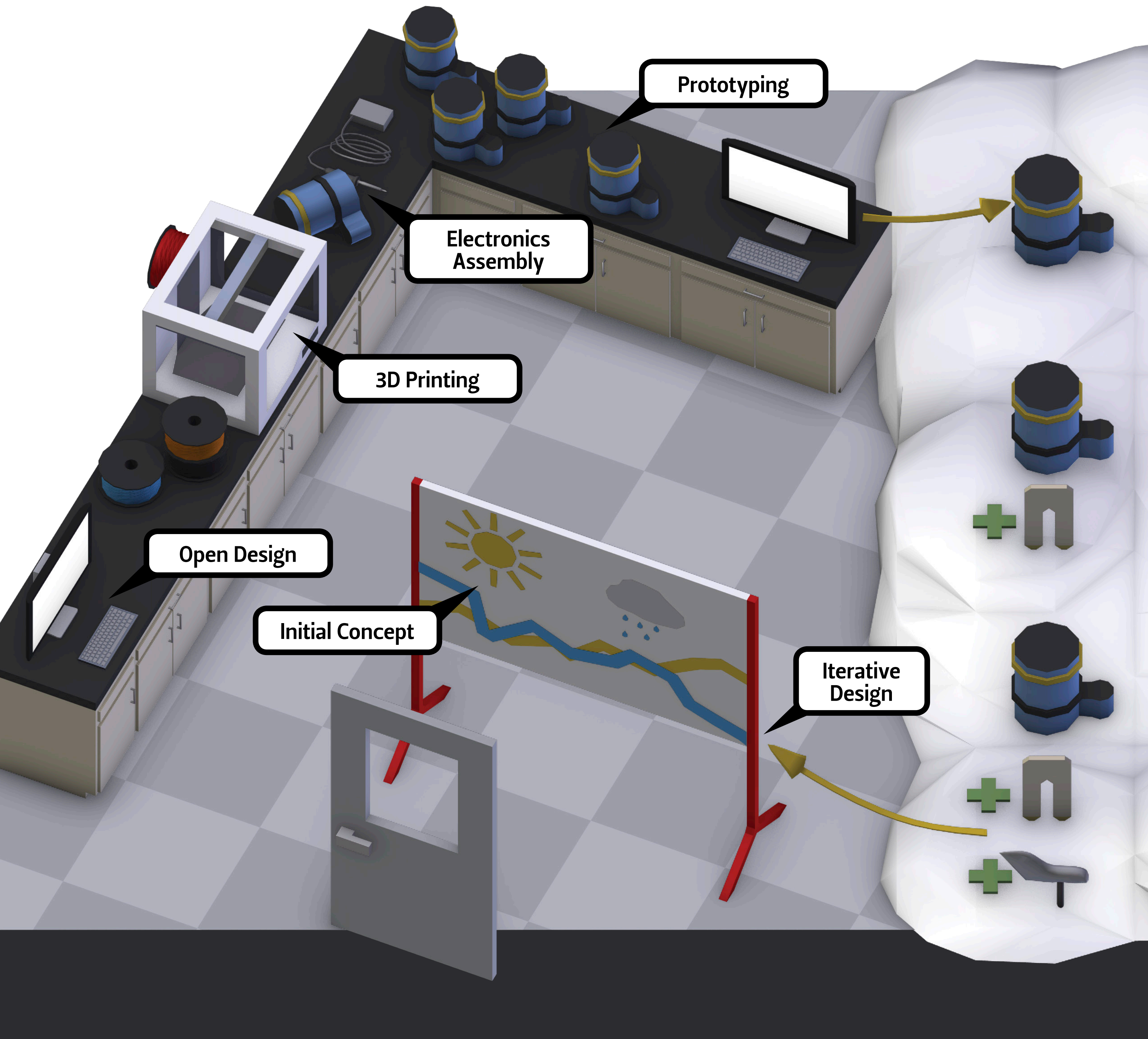
Armstrong's study challenges the long-held notion that salmon and trout habitat is all about cold water. "Places that are lethally hot during summer may be critically important because of the role they play in other seasons," he said. | **OAP**

Above: Bill Tinniswood, a biologist with Oregon Department of Fish and Wildlife, tags a hefty Klamath redband trout for a study he's conducting with OSU biologist Jonny Armstrong.
Below: The Williamson River, a groundwater-dominated tributary of Klamath Lake, is where most of the tagged fish were found to spend their summers.

OPEnS Lab:
collaborative design, printable technology

By Phillip Brown | Illustration by Alan Dennis

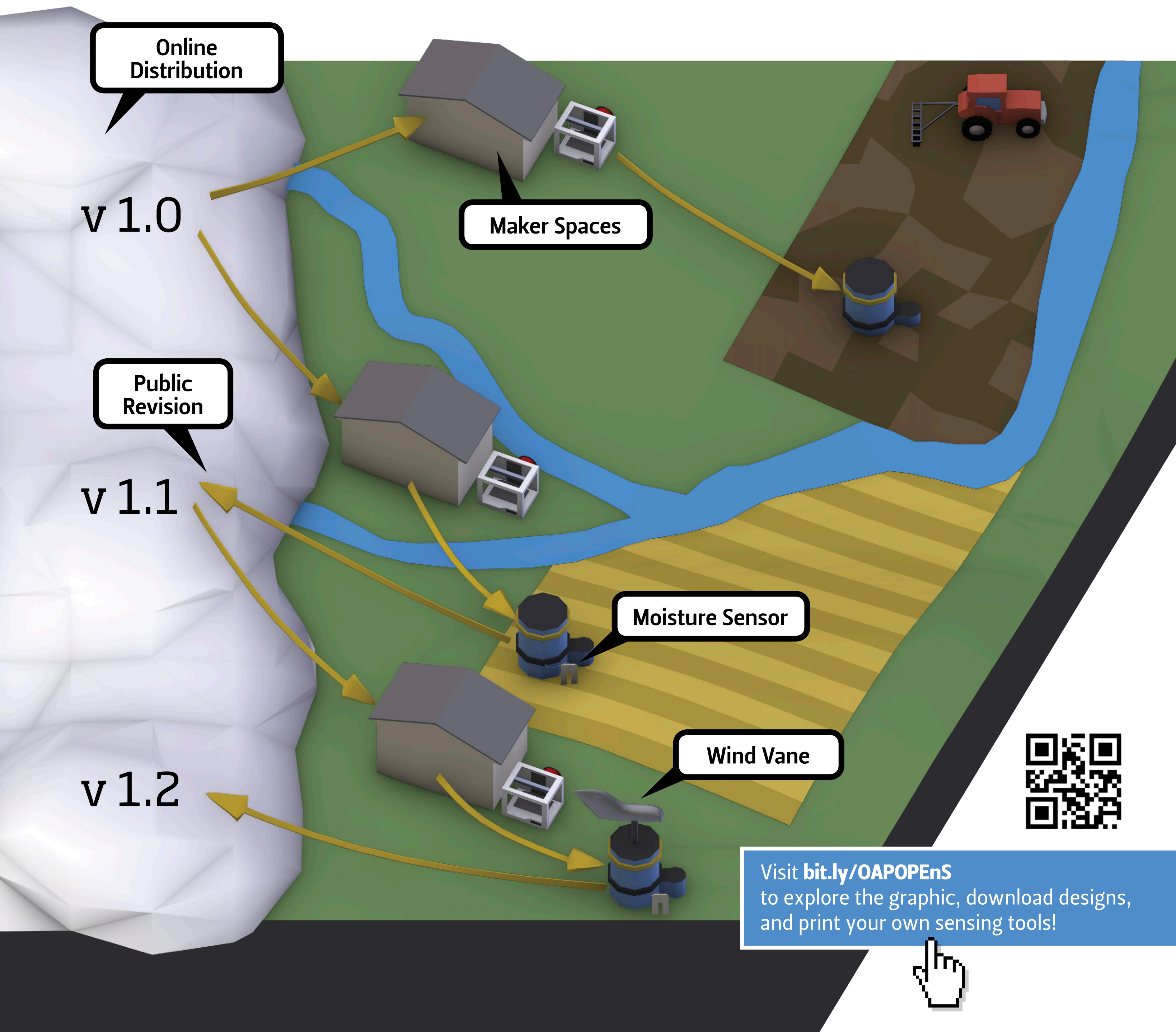
With its sloped ceiling and assorted gadgetry, OSU's OPEnS (Openly Published Environmental Sensing) Lab has an industrial loft vibe. Electronics workstations provide tools for tinkering, students discuss prototype designs on a computer screen, and lab staff collaborate with a professor to sketch new ideas on a whiteboard. A 3D printer hums in the background as layer upon layer of melted



plastic fuse together, making the latest iteration of a wind vane that can track temperature and humidity in addition to wind direction, pressure, and speed.

Focused exclusively on environmental sensing, the lab combines scientific expertise with technical innovation. John Selker, OSU professor of biological and ecological engineering, says the OPEnS Lab makes tools that help us better measure and understand natural and agricultural systems—things like soil samplers that read moisture and gas concentrations, or irrigation gauges that detect both the amount of rain and its rate of evaporation.

Those printed parts, however, aren't the only product. The OPEnS Lab also freely publishes their designs online for the public to download, print, use, or—better yet—improve. With each upload, Selker hopes to empower individuals around the world to "take the design and run with it and make it theirs." Working together—whether in the same lab or on different continents—farmers, faculty, students, and Extension agents can increase the cost-efficiency, ability, and accuracy of these innovative devices. | **OAP**



John Selker photo

Student designs improve fish farms in Africa

By Peg Herring

The Grand Challenge facing agriculture is how to feed 9 billion people by mid-century. Students in OSU's College of Agricultural Sciences are meeting that challenge with innovations to help African fish farmers produce food efficiently and sustainably.

According to the United Nations Food and Agriculture Organization, 1 billion people, largely in developing countries, rely on fish as their primary source of animal protein. As stocks of wild fish dwindle worldwide, fish farming could help meet the increasing demand for food by a growing global population.

Partnering with the Aquafish Innovation Lab at Oregon State, students in the Biological and Ecological Engineering department are using their Senior Design capstone course to design a low-cost, off-the-grid aeration system for small, rural fish ponds.

For more than 25 years, Aquafish Innovation Lab's director Hillary Egna has focused her work on sustainable, small-scale fisheries and aquaculture in developing countries. Sharing with students her experiences with African fish farmers and her long-standing relationships with African fisheries scientists, Egna introduced the students to a vexing problem: how to provide oxygen to an open pond where tilapia are raised for human consumption in a location where line-power electricity is not available. The students took up the challenge.

Ecological Engineering's Senior Design course challenges students to use all the skills they've learned to solve the kinds of complex, open-ended design problems they are likely to encounter in ecological engineering practice. This is the third year that the course has addressed this challenge from the Aquafish Innovation Lab. Egna keeps the students focused on big-picture goals and real-world limitations. Faculty from the Biological and Ecological Engineering department advise the students on technical aspects. Five months of class time, and many nights and weekends, result in an array of potential designs.

The first year, Egna and others judged the students' prototypes and chose two designs to field test in Ghana. The students travelled there in August 2015 with their OSU professor Ganti Murthy to work with colleagues at Kwame Nkrumah University of Science and Technology (KNUST) in Kumsai, Ghana. They installed their designs in separate ponds, monitored their effectiveness, and instructed the KNUST students on the maintenance and functionality of the aeration devices.

"The KNUST faculty and students really made the implementation of our designs possible," said Dylan Ferrell, one of the students who designed improvements to the system in Ghana. "It's one thing to design something thousands of miles away, but it's entirely different to implement it in a real-world setting."

As with most innovative ideas, once these were implemented, their designers saw the need for improvements. So, the following year's Senior Design Course took up the challenge to further improve the pond aerator design. In August 2016, three more students traveled to Ghana with ecological engineering professor John Selker to install design improvements that allow the system to run independent of energy fluctuations.

"This design challenge benefits ecological engineering students and faculty here at OSU and the students and faculty at KNUST in Ghana," said Dillon George, another student on the Ghana design team. "The bigger picture is to improve the efficacy of aquaculture as an industry in rural tropical and subtropical nations across the developing world." | OAP

Wastewater Miners

By Kathryn White

The toxic chemical soup generated from garbage in landfills is one of the most common liquids contaminating water supplies worldwide. This so-called landfill leachate is created as rain, melting snow, or the liquid waste itself seeps through garbage. Treatment of landfill leachate is one of the most costly and environmentally problematic challenges of modern wastewater treatment.

Graduate students Steve White and Hossein Tabatabaie in OSU's Department of Biological and Ecological Engineering have designed a way to treat landfill leachate to remove many of its pollutants and to reclaim resources such as metals and ammonia. Their design "mines" valuable metals from leachate, generates energy for local use, and cleans large volumes of water for irrigation. In that way, the students' innovation turns the waste treatment process from an expense to a revenue stream.

Most landfill leachate makes its way to municipal water treatment plants that are not designed to handle the toxic organic compounds it contains. These pollutants remain in the treatment plant effluent and are often dispersed on farm fields, where their impact on human health and the environment is poorly understood.

"The variety of compounds found in the leachate makes this problem go beyond a solely biological approach," says White. "We must look at the chemistry behind each of those compounds."

Their model is designed to sequentially precipitate, dry, and recover metals from the waste stream, while generating large volumes of water for agricultural applications. Ammonia is converted into ammonium sulfate crystals for fertilizer; and energy is generated from organic material through incineration.

White and Tabatabaie, semifinalists in the 2016 Portland State Cleantech Challenge, built a prototype of their model and presented it in September at the Oregon BEST FEST, a showcase of clean technology innovation. The students' presentation prompted meetings with venture capitalists from Wells Fargo, Dow Chemical, and a group from Saudi Arabia.

"It's a slick process," says Karl Mundorff, Director of OSU Advantage Accelerator/RAIN Corvallis, an organization that focuses on high-growth innovative start-ups. "These guys are using proven science in an innovative way to improve a system that currently is not working. In the end, they will save solid waste landfills a lot of money, create value-added products from the waste stream, and protect the environment." | **OAP**

OSU ecological engineers Steve White and Hossein Tabatabaie show the before-and-after results of their design to clean water and recover solids from landfill leachate.

iStock.com/Bill Oxford photo

TRACING THE MOVEMENT

by Ben Davis

OF WATER

“I study the drinking habits of plants,” says Stephen Good, a hydrologist in the Biological and Ecological Engineering department at OSU. Some plants pace themselves and sip steadily, while others are downright bingers, guzzling water all at once. Good is interested in how those natural tendencies respond to changes in the environment. His research involves measuring the soil moisture content in croplands over time, which provides insight into how and when specific plants consume water.

Understanding the conditions in which crops take up water can help growers create more efficient irrigation systems. It can help predict how plants will respond to droughts and floods. It can also help model future changes in ecosystems based on changing weather patterns and plant growth. In fact, Good is finding that vegetation affects the weather more than you might think.

Let’s begin with the water cycle that we all learned about in grade school. It lumped together several different processes under the single heading “evapotranspiration.” These include evaporation from lakes, rivers, and soil, as well as a somewhat different process—transpiration—by which plants emit water vapor through their stomata, much like we perspire through our pores. Scientists like Good are developing new methods that can separate the component of water delivered by transpiration and measure its contribution to the water cycle. In a recent study using data from NASA’s Aura satellite, Good estimated that transpiration surprisingly accounts for nearly two-thirds of all evapotranspiration globally. That’s a lot of exhaling plants.

But you might wonder: How exactly can you trace the origin of a drop of water?

Water consists of hydrogen and oxygen atoms; and within those atoms, there can be various numbers of neutrons. Atoms of the same element with different neutron counts are called isotopes. For example, three isotopes of hydrogen are abundant in nature: protium (with zero neutrons), deuterium (with one neutron), and tritium (with two neutrons). Heavier isotopes of hydrogen and oxygen (those with higher neutron counts) are the first to fall from clouds, which means they accumulate in higher percentages along coastlines and are more available for uptake by plants and animals. By measuring the ratio of each isotope in a water sample, Good can determine the origin of any given droplet.

Interestingly, water retains its isotope ratio even after a water molecule has made its way through the life cycle of a plant or animal. In crime forensics, water molecules extracted from a murder victim’s hair can be used to trace the victim’s movements before death. Isotope ratios in animal fur, scales, or feathers can be used to trace migration patterns, to determine whether a goose flew down from Canada, or a shrimp was caught in the Gulf of Mexico.

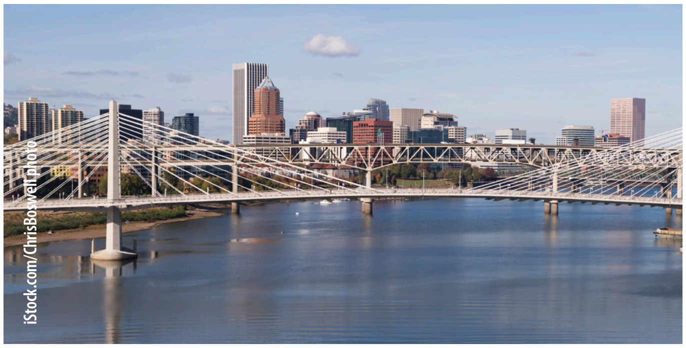
The most far-reaching use of isotope ratios, however, comes back to Good and his transpiration modeling. Good employs various methods to collect data, such as remote sensing with radar and satellite, to take measurements of soil moisture content on a global scale. With this, he develops a worldwide picture of plants consuming water in specific regions at specific times in relation to specific weather. In addition to plant intake, Good’s isotope research reveals how much atmospheric moisture is drawn from transpiration.

By measuring the ratio of each isotope in a water sample, Good can determine the origin of any given droplet.

Combining these data sets, Good creates maps he calls isoscapes, which look something like shaded relief topo maps, with the location of a specific isotope ratio assigned to a specific shade of grey on the map. Such maps provide a sharper, more detailed image of the water cycle by tracing the isotopic journey of each molecule through the guzzling and sipping of plants. As plants take up water through roots and release water vapor through transpiration, they are both responding to and affecting atmospheric changes. This is important information as Good and colleagues develop models of water availability under various climate scenarios to help us weather the future. | **OAP**

Willamette Water 2100 dives deep into the future of water

By Gail Wells



When you ask the average Oregonian to describe the Willamette Valley, the first thing you'll likely hear is, "It's wet." That seems obvious enough. If the Willamette Basin were a literal basin—like a flat-bottomed washtub—it would catch enough water within a year to fill it more than 5 feet deep.

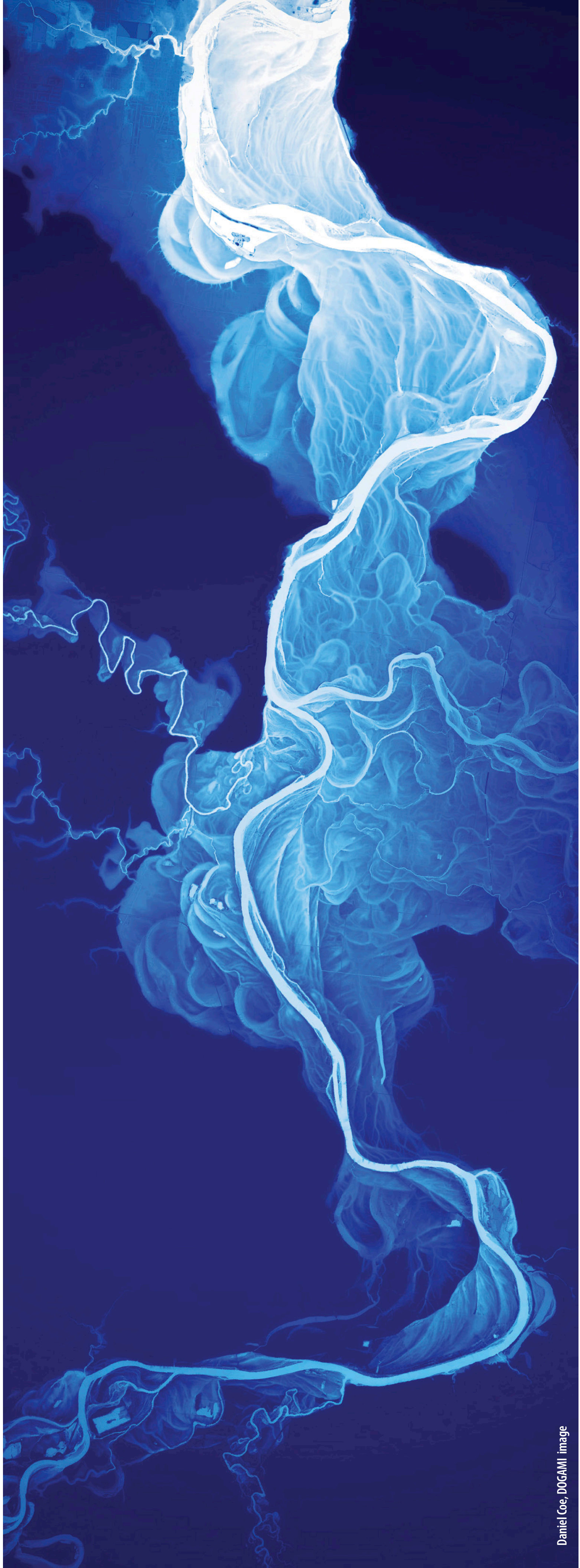
Yet that's not the whole story, says Sam Chan, an OSU Sea Grant watershed specialist. "It's really more accurate to say that there's a *perceived* abundance of water in the Willamette Basin."

Chan is one of 35 OSU members of a scientific team that just finished a massive 6-year modeling study called Willamette Water 2100. Their verdict: With a growing population and a warming climate, parts of Willamette country will likely face water scarcity over the next 90 years.

The Willamette River and its tributaries drain a watershed that amounts to 12 percent of Oregon's land area, holds 60 percent of the state's population and some of its choicest farmlands, and hosts its three largest cities: Portland, Salem, and Eugene.

"We hope our findings will help policy-makers and other decision-makers identify the most effective measures to help the people in the Basin mitigate some of these scarcities, or adapt to them," says OSU hydroclimatologist Anne Nolin, who leads the WW2100 team.

Above: Portland, Oregon, is the terminus of the Willamette River, where it joins the Columbia on its way to the Pacific.
Right: Using pulsed lasers, this LiDAR image shows a segment of the Willamette River between Albany and Salem.



WW2100 makes predictions of likely outcomes under 20 different scenarios, says team member William Jaeger, an OSU economist and coauthor of a new OSU Extension publication, "Water, Economics, and Climate Change in the Willamette Basin, Oregon" which presents the model's findings in detail.

"We started with the 'business as usual' scenario," he says. "That gives us a baseline prediction of where and when water scarcity is likely to increase. And then we asked the 'what-if' questions."

Such as: What if more farmers wanted to use irrigation? What if incentives were used to encourage water conservation in urban areas? What if the basin's 13 federal reservoirs were managed differently? What if urban growth boundaries were changed? Every tweak sends ripples through the fabric of the model, altering its predictions in small or big ways.

The WW2100 model is equipped to answer such questions because it's "a coupled human-natural system model, based on empirical data," says Jaeger. That means the model draws on a sturdy foundation of research to describe in detail the ways in which people change the natural world, and are changed by it, as they go about their lives: choosing where to build, how to manage cities and farms, how to use and protect forests and streams, and a host of other individual and collective decisions.

"That combination of human and natural dynamics is really rare in a model," Jaeger says.

The centerpiece of WW2100 is a software platform called Envision, developed by OSU ecological engineer and WW2100 team member John Bolte. Envision is the executive brain that enables all the different models to talk to one another, share data, and project water scarcity at different moments in time, across the whole basin and in the different watersheds that compose it.

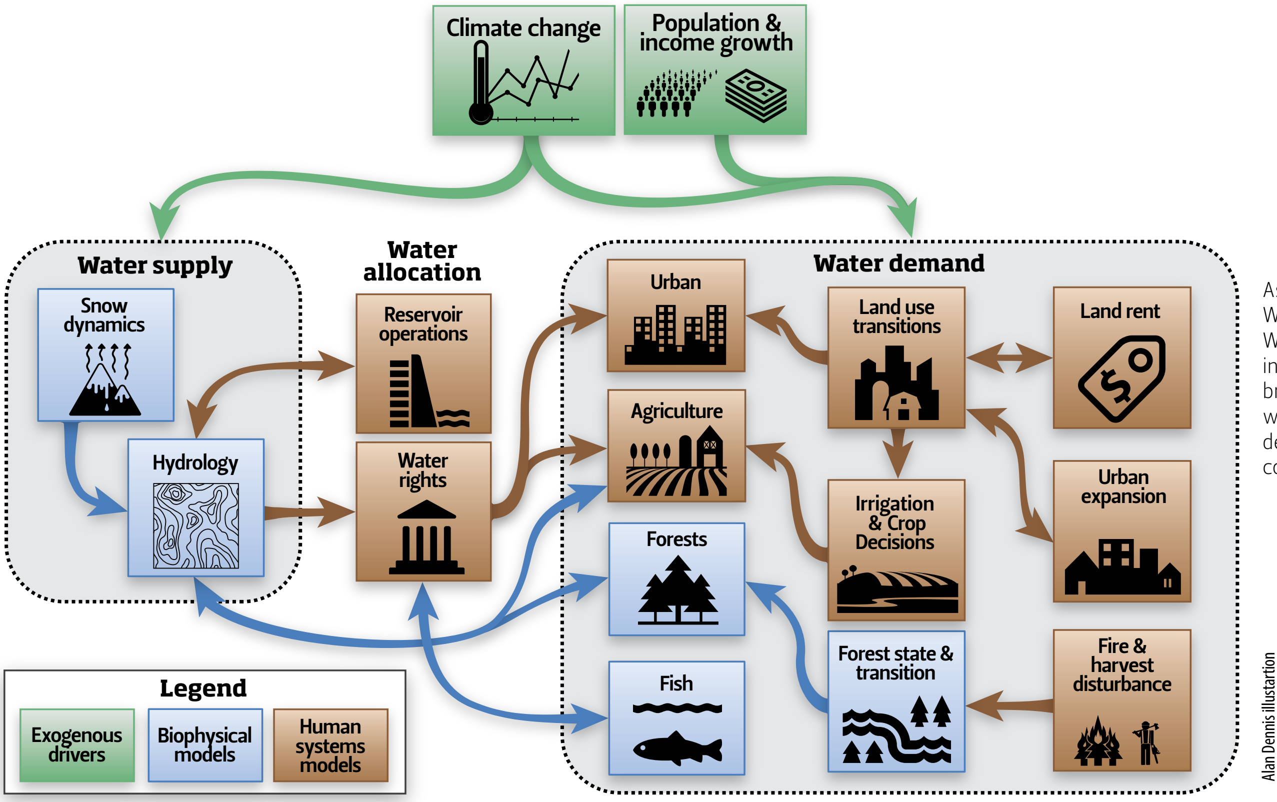
"We learned things from this coupled modeling that we couldn't have learned from projections from either natural dynamics or human systems alone," says Nolin. For example, it would seem obvious that a warming climate would have an impact on water. Yet the research team found that future patterns of water scarcity—when and where it will happen and how big an impact it will have—depend much more on the "people" side: rising incomes, population growth, urban expansion, farming practices, conservation measures. And they depend on how the available tools—water laws, land use practices, reservoirs, utilities management, environmental regulations—are used to allocate what water there is.

"We're fortunate here in the Willamette Basin," Nolin says, "because, unlike many places in the West, water is not yet a crisis." Nolin and her team hope WW2100 will help keep it that way by clarifying the choices along with the inevitable tradeoffs.

What we might expect: **key findings of Willamette Water 2100**

- Global warming will significantly reduce winter snowpack over the next decades, especially at lower elevations.
- Warmer, drier conditions in the mountains will stress forests, in turn increasing wildfires as much as ninefold, and eventually triggering shifts in forest ecosystems toward sparser, drier forests.
- Earlier springs will shift irrigation demand to start earlier in the season and may lessen demand in the late summer.
- Rising populations and incomes in metropolitan areas will increase urban demand for water. If neighborhoods get denser, water demand may grow more slowly.
- Urban growth will spill out onto neighboring farmland in some places, reducing demand for irrigation and increasing demand in cities. Even so, irrigation will continue to consume much more water than urban use.
- The 13 federal reservoirs on the Willamette and its tributaries represent the biggest mechanism for mitigating water scarcity over the next 90 years. But watersheds of undammed tributaries will be more vulnerable in drought years.
- Federal laws protecting salmon and other fish require leaving a lot of water in the streams—much more than is taken out for irrigation or urban use. Such environmental requirements are likely to increase in the future.
- Warmer stream temperatures will degrade habitat for cold-water species like salmon and trout, decreasing their populations and boosting populations of warm-water species like carp.
- For some uses, water may be abundant but unavailable, either because a given person doesn't have the right to use it, or because it costs too much to transport the water where it's needed.

What is a model?



As a model, Willamette Water 2100 integrates a broad range of water sources, demands, and contingencies.

Close your eyes and think of your third-grade classroom. Picture a poster on the wall showing the solar system: the planets Mercury through Pluto (back in the day) printed in streaks of yellow, red, and blue, big beads strung on a necklace of concentric rings circling a spiky yellow sun. If you were lucky, your teacher might have hung a three-dimensional version from the ceiling, a tippy mobile that rocked gently at every slam of the door.

You knew that these representations were not the real thing, but a simplified representation, showing the relationships among Earth, its sibling planets, and their governing star. That poster (or the mobile, if you were lucky) was a model.

A model can't contain every aspect of reality. (If it could, it would BE reality.) Rather, it contains the aspects of a given reality that are of interest to whoever is doing the modeling. Your teacher no doubt chose the solar system models as a good way to introduce eight-year-olds to their wider cosmic neighborhood. A more complicated model of the solar system might show, for example, the actual distances between one planet's orbit and the next—vaster than it's possible to capture in a classroom-sized poster or mobile. It might also represent the motion of the planets, which make it possible to predict an eclipse.

Models are an essential tool in science. To make them, scientists start with quantities of information discovered through empirical study. They comb through these data looking for patterns and significant relationships. Then they distill this knowledge into mathematical equations.

An equation is a model itself, of a pattern that holds true across a range of situations. $E = mc^2$, for example, describes the relationship between mass and energy whether you're on Earth, on the moon, or somewhere in a far-flung galaxy.

Most other models are not so universal as Einstein's famous one, but they are still useful. Models can represent processes both natural (the pull of gravity, the speed of light, the orbit of Saturn, the effects of air temperature on melting snow) and human-driven (migration into cities, urban water use, irrigation patterns among farmers of different crops).

When combined into a computer platform like Willamette Envision, the models enable scientists to test how different processes interact with and influence one another. They enable scientists, and also citizens and policymakers, to see how Plan A will produce a given set of effects by 2090, whereas Plan B will produce different effects.

The value of models like WW2100, say its scientists, is to make it possible for citizens and their policymakers to better understand future options and—it is hoped—choose pathways that lead to a future their grandchildren can live with. | **OAP**

Carolyn Van Houten, National Geographic photo

Antarctic future on thin ice

By Peg Herring

"Whales are the biggest animals that have ever lived on the planet; they're the ultimate ocean predators; and they represent the health of oceans," says Ari Friedlaender. "Where you find whales, you find healthy ocean ecosystems that can support a lot of life."

Friedlaender is an ecologist in OSU's Marine Mammal Institute whose research in the foraging behavior of whales and their prey has taken him to all the oceans on Earth. But it's the oceans of Antarctica that Friedlaender is most passionate about.

"Antarctica does not exist for our needs and desires," Friedlaender writes in his book, *Unframable*, in which he shares the beauty of Antarctica through the lens of his camera. "There is heuristic value for this place to exist and persist without our fingerprints scattered on it."

And yet, his research documents the undeniable fingerprints of climate change on the Antarctic, which he calls "the greatest wilderness on our planet." The waters around the Antarctic Peninsula support vast amounts of krill and high densities of krill predators, according to Friedlaender. Over the past fifty years, this region has warmed at a faster rate than any other on the planet, and the number of ice-free days during winter has increased by nearly a month. This has rearranged the distribution and abundance of krill, and whales.

Friedlaender offers a rare look at the disappearing world of Antarctica's whales in the new National Geographic show *Continent 7*. "It is imperative that we understand the rapid climate changes that are being observed," he says, "and how they will affect the relationships between sea ice, krill, whales, and the other predators that call the Antarctic home."

On the following page, Friedlaender shares one of his photographs of this Antarctic home and the whales that live there.

Depth of Field

Following pages: Antarctic minke whales in Wilhelmina Bay, Antarctic Peninsula. Image is from *Unframable*, by Ari Friedlaender.

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Chris Ho photo

The Willamette River ends its nearly 200-mile journey in Portland, Oregon. A new study reflects the future of the Willamette Basin.

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