A New Kind of Institute

It’s like nothing else in the United States.

The Montana Institute on Ecosystems studies the large landscapes and riverscapes of Big Sky Country and how they will be affected by environmental change, whether that change is in land use, climate or our forests, grasslands or water. Other environmental centers around the nation are based at a single institution, but the IoE employs the resources of the entire Montana University System to achieve its goals. It’s a new statewide model for research centers, and Montana is leading the way.

Formed in 2011, the institute is co-directed by Professors Ric Hauer of the University of Montana and Cathy Whitlock of Montana State University. Its start-up funding is from a five-year, $20 million grant from the National Science Foundation’s Experimental Program to Stimulate Competitive Research, as well as a $4 million state match.

More than 250 faculty members from across Montana, including those at tribal and two-year colleges, are IoE affiliates. Their research covers everything from the changing hydrologic regimes of floodplains to environmental policy and law.

“Our work encompasses a wide spectrum of research, from the natural sciences all the way to the cultural, human end of how people interact with their environment,” Hauer says.

“This special edition of Research View will offer a taste of what we do here at UM, but the IoE truly enhances science across the entire state.”

The institute offers research and internship opportunities to undergraduate and graduate students. Fellowships and stipends are available to attract the best and brightest graduate students to Montana. The IoE also works to foster interdisciplinary research, creating connections among researchers across campus and between campuses. In addition, it works to ensure scientists have the proper cyberinfrastructure to compete with the rest of the world.

“How do we respond to environmental change so that it leads to economic and lifestyle sustainability for the state of Montana?” Hauer asks. “That is the big question for the Institute on Ecosystems.”

Got Snow?

UM studies accuracy of measuring instruments

If snow falls on the mountain and no one is around to measure it, how much does it snow? That’s the question UM hydrology Assistant Professor Marco Maneta seeks to answer.

“We’ve been working in hydrology for a long, long time,” Maneta says, “but we still do not have an accurate way of measuring the total volume of precipitation in our mountains.”

That might sound surprising. In Montana, eager skiers look up the daily snowfall report. In summer, irrigators and river rafters check river flows. Each day, the weather report tells us how much rain or snow to expect. Our lives are saturated with precipitation reports in this mountainous country, where so much of livelihoods and recreation depend on water. In an era of climate change, drought and warming winters, Westerners are paying close attention to this finite resource.
Destructive though they may be, mountain pine beetles are impressive workers. No larger than a grain of rice, they use chemical communication systems to coordinate mass attacks, turn a tree’s defense mechanisms against itself and manufacture a type of antifreeze to survive winter.

When UM researcher John McCutcheon looks at a tree, he sees lunch. We’ve all witnessed the aftermath of this appetite — entire swathes of reddened forest, a blight creeping up to the timberline because warmer winters enable the beetles to climb to higher altitudes.

When UM researcher John McCutcheon looks at a tree, he sees two bacteria held up by sticks. He’s a microbiologist and a specialist in symbiosis, so he knows that all complex life has benefited from hosting very small organisms. In the tree’s case, the mitochondria and chloroplasts within its cells were once foreign bacteria that developed such beneficial relationships with their hosts that they eventually became part of the tree itself. McCutcheon studies the complex symbiotic associations between insects and microbes. Recently he’s turned his attention to the mountain pine beetle and two species of fungi that help them thrive on an abundant but nutrient-poor food source: trees.

The beetles have the respect of Diana Six, a UM scientist who’s studied them for 22 years. Sure, they cause problems — “I get mad when they kill trees in my yard, just like anyone else,” she says. “Maybe even more so, because I’m embarrassed.” But she also admires their resourcefulness. “These things have evolved in some really remarkable ways,” she says. Most remarkable to Six is the fact that they wouldn’t survive
a day without two species of symbiotic fungi that ride from tree to tree in suitcase-like pouches on the beetles' mouths.

McCutcheon and Six have teamed up to research the relationship between mountain pine beetles and these two fungi at the smallest possible level: their genetics. With a grant from the Montana Institute on Ecosystems, they are studying how these species help and hinder each other. Their findings may have huge implications on our understanding of pine beetle behavior, where they might strike next and what we might be able to do to stop them.

As far as McCutcheon and Six can determine, the story began millions of years ago with some star-crossed matchmaking between species. McCutcheon surmises that a beetle picked up a fungal partner that gave the beetle an unanticipated edge.

“When these organisms first got together back in time, it was really beneficial for the insect,” he says. “It allowed them to live in places they ordinarily couldn’t. It allowed the insects to spread across the globe.”

It should come as no surprise that the way to the beetles’ hearts was through their stomachs. The two species of fungi helped the beetles derive nutrients from wood, a plentiful but insubstantial food source. When pine beetles bore into the bark of a tree, the fungi in their mouthparts rub off onto the tunnel walls. The fungi colonize the tree, migrating into the xylem, where they bind nitrogen and amino acids and transport them back to the beetles feeding in the sugary phloem. The beetles snack on the fungi like we might swallow multivitamins.

“If we were going to eat total junk food and live on French fries, we’d have to take serious supplementation to keep going,” Six says. “That’s what this is like. The fungi are the critical link that allows the beetles to use the tree. Without the fungi we wouldn’t have mountain pine beetles.”

Like many cases of symbiosis, the relationship is one of evolving codependence. After millions of years of co-evolution, the beetles can only survive with these two specific fungi, and the fungi can only survive with these beetles, which they use as taxis to transport them from tree to tree. Simply put, the species are getting a little clingy. It’s a relationship that bewilders and fascinates McCutcheon. “They’re kind of like an old married couple,” he says.

“You get dependent on each other. That dependency, the way it evolves, is very interesting to us.”

McCutcheon knows from studying other symbiotic relationships that the more dependent a symbiont grows on its host, the more bankrupt its genome becomes. The symbiont no longer needs the genetic variation it would to survive in this world alone.

“They become very comfortable,” Six says. “They lose gene function. Eventually they may become so wimpy that if environmental conditions change, they can’t adjust.”

That dependency can imperil the beetles and their fungi. “Building a symbiotic partnership allows you to do things you couldn’t do before,” Six says. “But there’s a cost. They become domesticated.” With fewer genes, the fungi are less likely to have something in their arsenal to adapt to changing conditions. “Symbionts are at a higher risk of a rapidly changing environment than other organisms,” Six says. “That puts their hosts at risk as well.”

For now, climate change appears to be helping mountain pine beetles. Higher temperatures put stress on pine forests and allow the beetle larvae to survive the winter. But warmer weather will not be as kind to the fungi. When Six designed a model for a site in Idaho, she found that one degree of warming over several years would cause the beetle-fungi symbiosis to disintegrate. “That, of course, would be the end of the beetle at that site,” Six says.

To find out how the fungi might adapt to environmental change, McCutcheon, Six and their Montana Institute on Ecosystems graduate fellow, Daniel Vanderpool, sent away their genomes to be sequenced. Sorting the resulting data will be like assembling six 20- to 40-million-piece puzzles, McCutcheon says, but it will start shedding light on what adaptations these fungi are capable of, and how they might eventually limit the fitness of mountain pine beetles.

With McCutcheon’s background in genomics and symbiosis, and the two decades Six has spent researching these beetles and their fungi in the woods and in the lab, you could say the scientists themselves have a symbiotic relationship. It’s the sort of interdisciplinary duo the Montana Institute on Ecosystems was created to connect.

“We’re on the cusp of asking questions about how these things evolved,” McCutcheon says. “I’m excited. I’m really excited.”
As a young scientist in the early 1990s, Maury Valett thought he knew the meaning of ecological restoration. He first became intrigued while doing postdoctoral research along the Rio Grande. The enormous and storied river has been manipulated for centuries to irrigate farms and provide drinking water to cities. And for some time, dikes have kept the river from reaching the floodplains. That’s been good for people who have built on the floodplain but not so good for the ecology of the river. Fish use floodplain habitat for spawning, for instance, and the plains serve as ecological cleansing systems for the river.

“Floodplains only work if the rivers flood them — that’s why they are what they are,” Valett says. “You lose a lot of what the river is when the river can’t communicate with the floodplain.”

Valett jumped at the chance when Fish and Wildlife gave him and his University of New Mexico colleagues the opportunity to artificially flood the plain to see how the river responded. It was a scientific investigation that got Valett thinking — and intrigued — about how rivers might be restored. But it wasn’t until years later, after he moved back to his home state of Montana, that he found that outside of academia restoration projects rarely involve scientists.

“Ecological restoration is a procedure executed by people who own businesses,” says Valett, now a UM professor of aquatic biogeochemistry. “They follow formats laid out by the state or the federal government to introduce a certain structure and hope that it makes the natural system work in a certain way. There’s really been no place for scientists. And so I started looking into it.”

Scientists rarely get the chance to experiment with large-scale ecosystems because there’s no funding. Restoration projects, on the other hand, especially Superfund sites, often receive millions of dollars from the government. But these are projects that Valett says require fast-tracking protocols.

“Afencies don’t have the time and money and opportunity to test alternatives,” Valett says. “They can’t. They’ve got contracts and deadlines, and they’ve got money they’ve got to spend. They can’t say, ‘Let’s use a different approach’ — especially one that hasn’t even been tested.”

Valett decided he wanted to find a way to bring science to the restoration equation. The project that caught his eye was the $200 million cleanup of Milltown Dam, part of the largest Superfund site in the nation. Starting in 2010, Valett gathered a team to investigate the issue. Last year, with help from seed money through the Montana Institute on Ecosystems, he and his group of UM professors and graduate students collected data and submitted a multimillion-dollar proposal to the National Science Foundation. Specifically, they applied to the Coupled Natural and Human Systems program, which promotes interdisciplinary analysis of relevant human and natural system processes, as well as the complex interactions among human and natural systems at diverse scales.

But this was no ordinary proposal. Although Valett’s goal began with a sole focus on his passion for science, the scope and direction of the group’s research changed over time in surprising ways.

“We started to think about what ecological restoration is, and ultimately it’s about people and their perspectives and priorities,” Valett says. “There’s a social-ecological system there, and that’s what piqued my interest. I want to do the science. But in developing this proposal, I became interested in the people.”
The first person Valett recruited for his team was Jakki Mohr, UM Regents Professor of Marketing. Right away, he was intrigued by her perspective. “That conversation started my foray into social sciences,” Valett says. “Did you know that marketing is a social science? I didn’t. I started talking to her, and I asked if she’d be interested in the project. She said she was.”

Mohr recommended Ray Callaway, a world-renowned ecologist at UM, known by his colleagues as an innovator in biological sciences. Whereas Valett’s role focuses on aquatic-based ecology, Callaway’s role on the team was on terrestrial-based ecology, exploring plant communities as key aspects of restoration. Cara Nelson, a UM ecology professor and chair of the international Society for Ecological Restoration, also came on board. From the outside, the team clearly was a super-group of top-notch academics with different strengths — a little like the Avengers but without the costumes. But in reality, getting things off the ground was challenging.

“It took us probably a good year of biweekly meetings for two to three hours each to simply learn how to communicate with each other about our respective disciplines and the lexicon of our disciplines,” Mohr says. “Just getting the project going was difficult for all of us, but it was exciting at the same time. What we encountered in our communications during the meetings was simply a microcosm of the dynamics the restoration projects themselves encounter on a much bigger scale.”

It was those social science dynamics — the ones involving stakeholders such as managers, businesses, the public, contractors and consultants — that kept coming up in the group’s conversation.

“The questions we started asking didn’t have anything to do with the ecology of the river system itself but more about the fundamentals of how ecological issues interact with social character to guide success,” Valett says.

The IoE also played a role in the way Valett and his team began to think about their approach. The original goals of the IoE were to integrate environmental research between UM and Montana State University. But one of its other main features was integrating social sciences into the research.

“It specifically incorporates social science,” Valett says. “The idea of integrating social science into the field made us start to look at what are called social-ecological systems, a field related to the notion of sustainability and resilience.”

They also realized their team was not complete. They needed, Valett says, a “dyed-in-the-wool” social scientist. And so they brought in Libby Metcalf. Metcalf was, at first blush, a surprising addition to the group. But as a researcher of the human dimensions of natural resources, Metcalf had an angle the rest of the group didn’t: the knowledge of how to look at the social aspects of natural resource projects, crunch the data and build models.

“She’s a young, new professor,” Valett says. “She was green. But Jakki said, ‘That doesn’t matter. We’ll push the social part where it’s never gone before.’”

In addition, Laurie Yung was added to the team, given her expertise in qualitative research in the social science area of conservation and restoration. Once the group got the IoE seed money, they began conducting research on the Clark Fork River. Mohr, Metcalf and Yung brought on two graduate students — doctoral candidates Peter Metcalf and Dave Craig — to aid the team.

Mohr’s role in the project was to look into the perspectives of the contractors, consultants and business owners responsible for implementing the restoration work. She wanted to see where the gaps in communication were. For example, scientists might know the precise mix of vegetation for restoration, but does the person installing the vegetation know where to place the plants? Do they care?

“As academics, we’re always interested in building the bridge between academic sciences and research and applying those new techniques in the field,” Mohr says. “Given my expertise in commercializing innovation, it was a really natural thing for me to ask these consultants and agencies who were designing the plans how did they even pick the approaches they were using? What new techniques were they aware of, and what would urge them to try something new?”

Metcalf also spent time talking with people to gather data. She found that time was a factor in the way landowners and residents perceived and, ultimately, engaged with a restoration project.

“One of the big frustrations they have was the time it took to get things accomplished,” she says.

She also talked with natural, biological and ecological scientists to gauge their take on the social science aspect of restoration.

“It kept coming up that it was people who mattered in this process,” she says. “And that goes back in mind to our group’s original feeling that if restoration is going to be successful the social element needs to be understood, so it was kind of a confirming factor for us.”

Mohr and Metcalf focused on factors that benefit people. Nelson’s focus was, like Callaway and Valett, ecological benefits and how people impact them. Many times restoration projects aren’t monitored, which limits our understanding of the factors that lead to project success. And even when monitoring does occur, it often lacks the rigor needed to answer questions about project effectiveness. Nelson’s focus is not just the efficacy of the restoration but also — and this starts sounding complicated — the efficacy of the tools used for evaluating restoration success. In other words, when monitoring is being done, how effective is the monitoring itself?

“If we want to understand project outcomes, we’re going to have to monitor using efficient and effective protocols,” Nelson says. “And oftentimes, protocols are not adequate. We really need to bring a higher level of scientific sophistication to monitoring.”

Valett’s group has emerged at a prime time. Restoration is an $81 billion industry in the U.S., and in Montana there are projects aplenty. In addition, natural-resource management is moving toward a collaborative agenda. For instance, in 2009, Congress established the Collaborative Forest Landscape Restoration Program to provide funding for and direct agencies toward “collaborative, science-based ecosystem restoration of priority forest landscapes.”

Like true scientists, Valett’s group is waiting to see the evidence as to whether collaboration leads to success in ecological restoration. If their proposal is funded by the NSF, they will explore social-ecological factors in restoration success in three locations — the Clark Fork, salmon fisheries in Washington and national forests in the Sierras. It will likely be one of the first such integrative research projects of its kind.

There are very few academic programs in the U.S. that train students in the science, practice and human dimensions of ecological restoration, but in that regard, UM is ahead of the curve. Nelson directs an innovative undergraduate program in ecological restoration that trains students as ecologists and as managers, giving them the skills necessary to contribute to the repair of degraded ecosystems in an evidence-based way and to effectively engage relevant stakeholders in the process.

“I don’t think that it’s an overstatement,” Nelson says, “to say that UM is emerging as a leader in ecological restoration based on this program, the expertise of our faculty and — with the IoE’s support — these kinds of collaborations.”

— By Erika Fredrickson
Accuracy and representativeness of these measurements matter. That’s why Maneta has come up with a model to characterize spatial uncertainty and to estimate the effect of using inaccurate precipitation levels on our hydrologic predictions. His research centers on the Bitterroot Mountains, ideal for proximity to UM and for the north-south direction of the range. Storms from the west strike the peaks perpendicularly for a classic look at mountain snowfall accumulation.

Maneta knows people who study those readings religiously won’t appreciate learning they are suspect. But to demonstrate the problem, he picks up a marker and sketches a mountain on his office whiteboard. Then, he inserts a small square part way down from the summit to represent a SNOTEL sensor.

SNOTEL is short for Snow Telemetry, a system run by the Natural Resources Conservation Service across the western U.S., designed to collect snowpack and other meteorological data that, in turn, produces water supply forecasts. A SNOTEL station measures snowpack water content at a location using a pressure-sensing snow pillow and also collects snow depth information, precipitation and air temperatures.

Next, Maneta draws the cloud laden with moisture approaching the mountain, ascending, and then releasing moisture at greater amounts above the SNOTEL sensor. The problem with SNOTEL, Maneta says with an emphatic tap on the sensor. The problem with SNOTEL, Maneta says with an emphatic tap on the sensor. The problem with SNOTEL, as climate scientists are predicting, could we detect it?” Maneta asks.

He strives to measure the correct volume of water that drives the ecology of plants, as well as the flows of streams and rivers that support fisheries. To do that, he and his graduate students have developed models that combine physics with field observation. Maneta’s work connects directly with the key principle of the Montana Institute on Ecosystems. Weaving the various science fields together contributes to a holistic picture of the world we live in. Andrew Wilcox, a UM geomorphology professor, says he depends on Maneta’s findings to study the way water carries sediments and, in turn, shapes stream channels and habitats for fish and other aquatic organisms. Ultimately, he evaluates which types of streams across river networks are likely to be more vulnerable or resilient to climate change, an effort that Wilcox hopes will help guide river restoration and management.

“Marco’s models are allowing us to understand the hydrology of a Bitterroot basin at a detailed scale,” Wilcox says. “Even where there are no water gauges, his models are giving us estimates of stream flow throughout a river network.”

To provide a more precise model of precipitation, Maneta’s graduate students climb high into the mountains to conduct field checks on the equipment that helps to refine the model. Eventually, field observations will be contrasted with Maneta’s hypothesis to confirm if SNOTEL sites underestimate precipitation in mountainous country.

“You might think that more precipitation would be detectable in the stream flow record, but if we are also seeing a lot more greening of plants and evapotranspiration, that can make up the difference,” he says.

Maneta, however, focuses on the hydrology and relies on geomorphologists, ecologists and social scientists to fill in the story. He credits support from the IoE for the Bitterroot watershed project, with additional grants from US-EPA, the NASA EPSCoR/Montana Space Grant Consortium program and the Montana Water Resources Association.

More than a professor who builds models on computers, Maneta freely admits to a lifelong passion for freshwater as a life source. From his childhood growing up in Spain near one of its major rivers, the Guadiana, he learned early on about the importance of water and the rules people make to govern its use to assure a future for the fertile farms of his homeland.

He pursued hydrology and eventually moved to the U.S. After completing his postdoctoral work at the University of California, Davis, he moved to UM in 2009 as an assistant professor in the geosciences department.

If we are to understand the trees, plants, wildlife and how we as people live within our watershed, Maneta believes we first must know the hydrology, a field that may sound technical but at its heart lies the beauty of the water itself.

“There’s something primal about flowing water,” Maneta says. “It’s like watching a fire burn. What you’re seeing appears on one hand predictable and on the other random.” —By Deborah Richie
**Connecting Campuses**

Graduate student group works to promote interdisciplinary research

Interactions interest Mandy Slate. As a UM graduate student in plant ecology, she studies how mosses and other flora interact with one another and the microbial community. She also works to increase interactions among her fellow grad students through an innovative new program funded by the Montana Institute on Ecosystems.

A self-described people person, Slate hit the ground running when she arrived on campus a year and a half ago, attracted to UM by an IoE fellowship and outstanding faculty. She immediately sought out graduate students from all disciplines to gauge interest in starting an informal monthly meeting where they could discuss research ideas.

“As far as funding agencies go, ‘transformative’ and ‘interdisciplinary’ are popular buzzwords, so the need to include this mentality into our research is something we are all aware of,” she says. “Already this group has helped us get to know people outside of our departments, which can sometimes be challenging. Our goal is to get people talking and exchanging ideas, and hopefully this will lead to collaborative research.”

Slate and the other grad students applied for and received a small grant from the IoE to rent spaces and pay for meeting supplies. The students also held a retreat last summer at Glacier National Park. The group became more formalized as it grew, taking the name Interdisciplinary Collaborative Network.

Today, the ICN has spread to Montana Tech in Butte and Montana State University in Bozeman. The goal is to get graduate students of different disciplines working together and exchanging ideas between universities. “We would love to have summer retreats where ICN members from the different Montana universities get together. We want ideas flowing among the campuses.”

She says the ICN has grown to about 50 students at UM and it underwent a fundamental change at the beginning of this semester when they began hosting a for-credit seminar series.

“Even with monthly meetings, it was rough getting everyone together,” Slate says. “Grad students, as a subset of people, are pushed to their limit, and it’s hard to find time even if you want to, so this new structure has been amazing.”
The goal of the new seminar series is to get students to thoroughly understand interdisciplinary research. Professors from different disciplines are invited to present lectures together to both demonstrate and discuss collaboration. The series also involves workshops to help students develop and implement professional skills.

Slate says the ICN gives students the opportunity to “bounce ideas off people from totally different disciplines and practice talking about their oftentimes narrow subset of knowledge with someone who is not a part of that field. During a recent meeting, we each had five minutes to present our research to people from fields as disparate as molecular biology, ecology, forestry and geography, and we had to make sure they all understood. It was an incredible experience.”

Slate says that besides instilling in its student membership the importance of interdisciplinary research, the ICN also promotes mentorship, networking and educational opportunities for grad students.

“People are really stepping up to the plate, coming to the seminars and pushing themselves outside of their boxes,” she says. “And it’s totally going to pay dividends on an individual and university wide basis.”

“We always wanted to do more to reach grad students with the IoE and ideas around interdisciplinary research,” IoE Director Ric Hauer said. “Then Mandy arrived on campus with all her energy and just made it happen. The ICN has really taken off. Connecting peer researchers among the graduate students has made the ICN a winning idea, but Mandy has been the catalyst. It’s amazing what one person with vision can accomplish on the UM college campus.”

To learn more visit http://www.interdisciplinarycollaborativenetwork.org.

— By Cary Shimek