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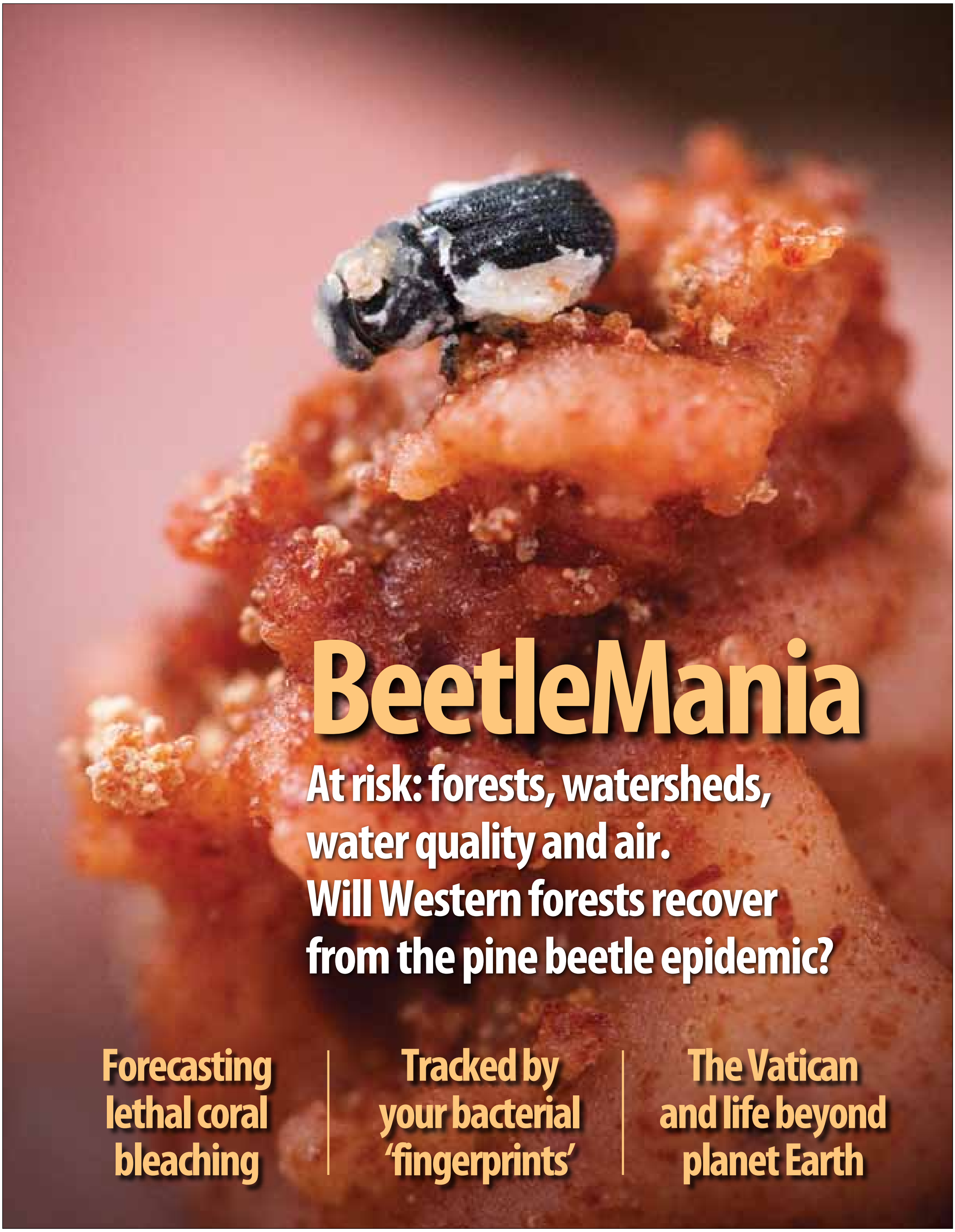
COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES



BeetleMania

At risk: forests, watersheds, water quality and air. Will Western forests recover from the pine beetle epidemic?

Forecasting lethal coral bleaching

Tracked by your bacterial 'fingerprints'

The Vatican and life beyond planet Earth

On the cover A pine beetle stuck by the sap that a tree used to expel it. Morgan Heim/CIRES

See the seals? Researchers have begun flying Unmanned Aircraft Systems (UAS) with cameras to help them track seal populations in the rapidly changing Arctic. Can you find the seals in this image? Get the answer and read more about the research on **page 19**.

Eeewwwww!

The average human hand has about 150 species of bacteria living on it.

Source: Fierer 2009

During a mountain pine beetle epidemic, beetles emerging from an infested tree can kill at least two trees the following year.

Source: Colorado State University Extension Service

11 million pounds

of chemical pentachlorophenol (PCP) had been produced in the United States as of 2002. The chemical is still used as a wood preservative; many other uses have been restricted.

Source: U.S. EPA

8,200 feet

The elevation below which American pika rarely live in the southern portion of their range (including parts of New Mexico, Nevada, and California). In the northern portion of their range, American pika have been observed near sea level.

Source: U.S. Fish and Wildlife Service

"The Vatican has a long history of interest in astronomy. The idea that life might be found elsewhere … would be considered as evidence of God's magnificence."

Read more about Shelley Copley's Vatican visit on **page 21.**

Bleach Alert!

NOAA/CIRES tool gives advance warning of coral-stressing heat

Warm water can kill coral, and the "bleaching" of coral reefs around the world, often associated with heat stress, has become a critical problem in reef ecosystems. Bleaching occurs when stressed corals expel symbiotic organisms that give corals their color and help provide them with food. So CIRES researchers and colleagues developed a new tool to forecast warm water episodes. The still-experimental Coral Bleaching Outlook is a companion to NOAA Coral Reef Watch's real-time satellite monitoring of ocean temperatures. The Outlook uses models and observations of sea surface temperatures to forecast temperatures one week to three months in advance. NOAA and CIRES researchers won a Silver Medal for their work on the outlook.

Learn more

Visit cires.colorado.edu/about/accomplishments/performance to learn more about CIRES awards.

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Morgan Heim/CIRES

A climate for pikas

CIRES analysis helps federal biologists make protection decision

American pikas, little rabbit-like mammals that live on cool and rocky high-altitude slopes, have become a symbol of climate change impacts for some environmental groups. They often cannot tolerate the relative warmth of valleys, and so if climate change forces their preferred habitat upslope, populations could be left isolated, on "sky islands" of good habitat.

In 2007, an environmental group requested that the U.S. Fish and Wildlife Service (FWS) assess threats to the mammal—especially climate change—to see if pikas warranted protection under the Endangered Species Act. The FWS sought help from NOAA— one of the first times their expertise in climate change has been called upon for a species status review.

TheScience

For the first time, the U.S. Fish and Wildlife Service sought NOAA's climate expertise for a species status review.

"We were approached by Fish and Wildlife to conduct a rapid review of the area's climate that they could use to inform their decision on pika status," said Andrea Ray, with the NOAA/CIRES Western Water Assessment (WWA). "We brought different threads of scientific study together to bear on the particular problem and provided it in about six months so FWS could meet their deadline," she said.

Pika generally live in alpine and subalpine rockfields, and their range includes mountainous regions in the U.S. and Canadian West.

In February, Ray and CIRES' Joe Barsugli, Klaus Wolter, and Jon Eischeid (all with WWA) completed a 47-page analysis of observed and projected climate changes in pika habitat. The team assessed climate observations at and near pika locations; and projections from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment report. They also "downscaled" the IPCC projections, to predict future climate patterns in 22 specific pika locations.

The research team found that for pika habitat, the average summers of the middle of this century will be warmer than the warmest summers of the past several decades, by about 5°F. Observing stations in parts of Nevada and Oregon show summertime warming of 2-4°F during the past 30 years. These findings are consistent with the large-scale warming projected by the IPCC global models.

The trends identified in the NOAA report are probably enough to harm some pika populations, especially those in low-elevation, higher-temperature parts of the Great Basin, FWS wrote in its assessment.

"However, these losses will not be on the scale that would cause any species, subspecies or distinct population segments of pika to become endangered in the foreseeable future," FWS said, declining to designate federal protection to the species. "We believe the pika will have enough high-elevation habitat to ensure its long-term survival."

Learn more
Visit the Western Water Assessment at www.esrl.noaa.gov/wwa.

Touchy subject

Recent research shows that we're all walking microbial habitats ... women just a little more so

iStockphoto

When running around the playground as kids, it was usually the boys who were thought to have more cooties. But a new study shows that when it comes to a handshake, women harbor more varied bacteria than men.

Noah Fierer, a CIRES Fellow and assistant professor of ecology and evolutionary biology at the University of Colorado at Boulder (CU-Boulder), looked at the microbial colonies making their homes on human hands. He found more than 4,700 species of bacteria distributed across 51 people. The average palm, he discovered, hosts about 150 different bacteria species. And when separated along gender lines, women, well, they house up to about 30 percent more kinds of microbes than guys.

Inevitable jokes aside, Fierer's study, co-authored by Micah Hamady of CU-Boulder's computer science department, Christian Lauber of CIRES and Rob Knight of CU-Boulder's chemistry and biochemistry department, illustrates the magnitude of bacterial biodiversity on the human body.

"I view humans as 'continents' of microscopic ecological zones with the kind of diversity comparable to deep oceans or tropical jungles," Fierer said. "Today we have the ability to answer large-scale questions about these complex microbial communities and their implications for human health that we weren't even asking six months or a year ago."

By focusing on a technique known as "metagenomics"—sampling DNA directly from the microbe community—Fierer zoomed in on the lives of bacteria with a high-powered sequencing machine, distinguishing about 100 times more gene sequences than found in previous studies of skin bacteria. Standard skin culturing misses many of the microbial hitchhikers, his study shows.

TheScience

DNA sequencing allows researchers to zero in on the particular bacterial coverage on a person's body.

No need to go nuts with the hand sanitizer, however. Most bacteria don't cause illness, and can even help protect against getting sick, said study co-author Knight.

As for the gender gap of microbial distribution, there could be several reasons for the difference. Women tend to apply more moisturizer and makeup, both of which could be sources of microbes especially because they tend be reused. Nature has its role too, including differences in sweat and oil glands, hormones, and pH. One thing's for sure, whether on the palm of woman or man, people are planets when it comes to bacteria.

A bug's-eye view on the world

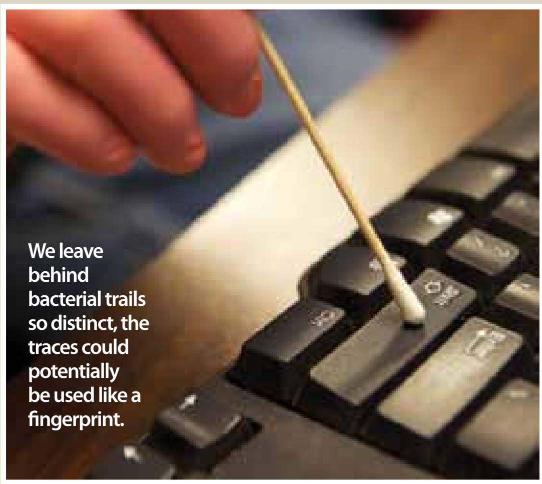
For bacteria, getting respect can be hard. A bit of a boost came recently when Wisconsin declared *Lactococcus lactis*, the "bug" responsible for making all that yummy cheese, the state microbe. Now the little critters are getting more 'cred' from CIRES. Here are a few of the ways CIRES scientists are upping the WOW factor of the microbial world.

Human bodies, microbial planets

Microbial diversity doesn't just apply to a person's hands. A bacterium that lives on the forehead might turn its flagellum up at real estate on the elbow. CU-Boulder's Rob Knight, Noah Fierer, and colleagues mapped bacterial communities across 27 sites on the human body and found that different zones host unique types of microbes. Not only that, but one person's bacterial makeup likely differs from another.

Bacterial crime fighters

Turns out when we touch things such as a computer keyboard or mouse, we leave behind an identifying trace of bacteria. These buggy clues could eventually play a role in solving who-done-its, as the microbes we leave behind are so distinct they act like a bacterial fingerprint. There's still work to do in order to sort out the details, such as distinguishing between multiple users of an object. But lawbreakers beware: some day investigators might nail suspects after swabbing for bacteria in crime scenes clean of prints or DNA.



We leave behind bacterial trails so distinct, the traces could potentially be used like a fingerprint.

Steve Miller/CIRES

The leafy loyalty of plant microbes

Trees, too, boast their own bacterial signatures, suggesting that trees and their "bugs" share a close symbiotic relationship. Noah Fierer and his team sampled bacteria from trees of several species and found each species with its own consistent microbial community. Unlike people, whose skin bacterial communities may differ from person to person, trees of the same species likely harbor similar types of bacteria, even if those trees live on different continents from one another.

Gales, fires, and beetles—oh my!

Ecologist Carol Wessman: how much can a forest stand?

When fire decimates the site of an experiment, some researchers might throw their hands up in dismay. Not so for CIRES Fellow and profesor of ecology and evolutionary biology Carol Wessman.

"My first thought was, 'This is cool,'" said Wessman. "Now things are getting really interesting."

Wessman's research is focused on the impacts of multiple disturbances on forest ecosystems. Until 2003, she had been studying a region in the Routt National Forest of northwestern Colorado that had suffered a catastrophic blowdown in 1997, and had then been partially salvage logged in 1999. Wessman was comparing metrics of forest recovery between the two.

TheScience

After a blowdown, logging, a fire, and a pine beetle infestation, how do those events affect a forest ecosystem's recovery from one or all four?

Then came the fire.

The 2002 Mt. Zirkel Complex Fire, which consumed more than 12,500 hectares, may have destroyed Wessman's experiment. But she simply took it as an opportunity to investigate a key ecological question: just how much can a forest stand?

"I am interested to see if there is a limit to the number of severe disturbances that a forest can experience before its ability to regenerate breaks down," said Wessman. "Do the effects of different disturbances accumulate? Do the disturbances interact?"

Wessman's research is critical for those who want to understand the future of forests and the services they provide, from biodiversity to clean water and carbon storage. Climate change and other human-forest interactions are expected to disturb forests with greater frequency, extent, and intensity. The effects of such disturbances are likely to have far reaching economic and social consequences. Better understanding of how forests will respond could help forest managers better plan for the potential stormy waters ahead.

Studying forest regeneration

Since the fire, Wessman and her students have been visiting the differently affected regions of the forest to meticulously log the fine details of forest regrowth. They measure the soil temperature, water content and nitrogen availability at 23 sites, and map the location, height, and species of every new seedling.

Prior to the fire, Wessman had found that regrowth in the areas that had been logged after the blowdown was slower than that in the "blowdown only" regions; fewer new seedlings were observed and the rate of growth for existing seedlings was reduced. It appeared that while the forest could recover from a single disturbance, multiple disturbances proved more challenging.

After the fire, however, some interesting and contradictory results began to emerge. Wessman found seedlings and new growth in the sites where the salvage logging had taken place, but not in the areas where just the blowdown had occurred—a reversal of previous results.

"The research has provided a really good example of the cumulative and interactive effects of the disturbances. The various permutations of the disturbances interact quite differently and produce quite different measurable results," said Wessman.

Predicting the impacts of beetle kill

While Wessman's besieged experimental plots were struggling to recover from the effects of multiple disturbances, the Routt National Forest—with many other forests in the Western United States—was hit with another catastrophe: beetle kill. The mountain pine beetle has devastated large regions in the Routt National Forest and District Rangers estimate 600 acres of the forest land are logged a month to remove affected trees. Moreover, the beetles have impacted both Wessman's "control" forest and regions where the fire was less severe, effectively burrowing their way into her research.

Wessman, however, believes the latest disturbance simply adds another layer to her experiment. "The question is how will the beetle kill interact with the other recent disturbances as it hits along the margins and in the remaining areas of green forest? The whole area is undergoing change," she said.

Wessman also hopes that the insights gleaned so far will provide useful information in predicting how these subalpine ecosystems will recover from the beetle kill. "Forest regeneration and nitrogen cycling in beetle-killed stands may parallel the blowdown areas in some ways, because in both cases the overstory is dead," she said.

Ultimately, however, she hopes that her research will inform some of the questions faced in a climate of unpredictable change brought about by warming temperatures.

"How resilient are our forests to more frequent, and perhaps more extreme, disturbances? And how do we (humans) have to adjust to accommodate those changes?"

Photos/Jane Palmer

StudentFocus: Brian Buma

Carol Wessman's graduate student Brian Buma is studying ecological diversity patterns following major disturbances in forests.

"We suspect more diversity or less diversity is a function of how much disturbance a site has accrued," said Buma. "How do communities reorganize after disturbances? What sort of plants come in?"

To gain a large-scale perspective on those questions, Buma analyzes remote-sensing data obtained from aerial surveys by the U.S. Forest Service, to determine the relationships between the different disturbances across the landscape.

"It's good to get concrete numbers in a spatial sense over the whole landscape," said Buma. "Then you can draw these large-scale interpretations which is really hard to do when you are just standing on the ground."

Brian Buma earned a Graduate Student Research Fellowship for his work. CIRES offers two graduate fellowships, ranging in support from a summer or single semester to four years. Visit our website to learn more about CIRES fellowships.

Learn more about CIRES fellowships at cires.colorado.edu/education.

Don’t count on the trees

Forests not likely to counteract warming

Contrary to conventional belief, as the climate warms and growing seasons lengthen, subalpine forests will soak up less carbon dioxide (CO_2) than they used to, according to research by CIRES Fellow and biology professor Russell Monson and his graduate student, Jia Hu.

As a result, more of the greenhouse gas will be left to concentrate in the atmosphere.

“Our findings contradict studies from other ecosystems that conclude longer growing seasons actually increase plant carbon uptake,” said Jia Hu, a graduate student in the University of Colorado at Boulder’s Department of Ecology and Evolutionary Biology.

Working with Monson, Hu found that while smaller snowpacks tended to advance the onset of spring and extend the growing season, they also reduced the amount of water available to forests later in the summer and fall. The water-stressed trees were then less effective in converting CO_2 into biomass. Summertime rains were unable to make up the difference.

“Snow is much more effective than rain in delivering water to these forests,” said Monson. “If a warmer climate brings more rain, this won’t offset the carbon uptake potential being lost due to declining snowpacks,” he said.

Drier trees also are more susceptible to beetle infestations and wildfires, Monson said.

The researchers found that even as late into the season as September and October, 60 percent of the water in stems and needles collected from subalpine trees along Colorado’s Front Range could be traced back to spring snowmelt. They were able to distinguish between spring snow and summertime rain in plant matter by analyzing slight variations in the water molecule’s hydrogen and oxygen atoms.

The results suggest subalpine trees, such as lodgepole pine, subalpine fir, and Englemann spruce depend largely on snowmelt throughout the growing season.

“As snowmelt in these high-elevation forests is predicted to decline, the rate of carbon uptake will likely follow suit,” said Hu.

Subalpine forests currently make up an estimated 70 percent of the western United States’ carbon sink. Their geographic range includes much of the Rocky Mountains, Sierra Nevada, and high-elevation Pacific Northwest.

CIRES’ Innovative Research Program is designed to stimulate creative and collaborative research. IRP projects often produce relatively quick results that form the foundation of a proposal for a more substantial grant.

Pine beetles' impact leaves the ground, affects the air


Steve Miller/CIRES

A famous U.S. politician once quipped, "Trees cause more pollution than automobiles do." The statement was widely derided, but it contained a kernel of truth: trees and the soil surrounding their roots do produce carbon compounds called volatile organic compounds (VOCs). VOCs can interact with anthropogenic emissions—nitrogen compounds from car tailpipes and power plant stacks, for example—to form lung-damaging ozone smog.

CIRES researchers are trying to understand how VOC emissions from Colorado's high-country forests will change as mountain pine beetles invade, killing lodgepole pines and dropping needles and branches to the ground.

"When you have a significant part of the state overrun with beetles, as Colorado is, it's going to affect the atmosphere," said CIRES Fellow Joost de Gouw. "The question is, how?"

De Gouw is working with CIRES Fellows Russ Monson and Noah Fierer to take advantage of a decade-long history of forest experiments at the University of Colorado's Mountain Research Station near Nederland, Colorado. Mountain pine beetles are just beginning to arrive at the site, but Monson's group has been working there for more than 10 years, trying to understand how climate change alters the carbon dioxide (CO_2) cycle in forests.

Part of the ecological research has involved girdling groups of trees—removing wide strips of bark to slowly kill trees by breaking the link between their needles and roots. The idea was to distinguish between CO_2 emissions by tree roots—which would be affected by girdling—and emissions by soil microbes, which would not.

Serendipitously, the research created a timeline of beetle-like disturbances, with some of the trees girdled a decade ago (they're now dead); and others girdled just last year (stressed, but still alive).

It seemed like an ideal setup for studying how VOC emissions change as trees die, Monson said. "Joost had pioneered the development of an instrument that pretty much captures the whole range of VOCs, and he had the experience with similar data. We had the site, and Noah (Fierer) had a graduate student who was interested."

TheScience

CIRES researchers study how a pine beetle outbreak may affect gas emissions by trees, litter, and soil microbes.

The three Fellows applied for and received an Innovative Research Grant from CIRES, and set up a proton transfer reaction mass spectrometer to collect emissions data from mountain forests during the summer of 2009.

CIRES graduate student Chris Gray is beginning to pore through the data. In theory, he said, one might expect VOC emissions from soils to spike up as trees drop needles and branches and microbes in the soil begin to decompose some of that litter. There's some evidence, from other studies, that plants under certain kinds of stress emit more VOC.

Within a few years, as the "easy-to-decompose" material is broken down, VOC emissions may drop back down again, Gray hypothesized. "But this is all kind of new research, so we're not sure," he said.

Monson said it's still not certain that the current beetle outbreak is a result of climate change, "but there is strong reason to believe that trees that are more stressed are more vulnerable to attack by beetles." He and others suspect that increasing temperature and decreasing moisture availability in the mountains are stressing the trees—and girdling clearly has stressed them, too, Monson said.

During the summer of 2009, he and a graduate student found beetles "zeroed in on the trees that had just been girdled... those trees acted like magnets."

Learn more

Visit cires.colorado.edu /science/pro/irp.

Morgan Heim/CIRES

Dead trees don't drink

How will mountain pine beetles—and attempts to control them—affect aquatic ecosystems?

TheScience

How are Colorado's drinking water and the ecosystems in the watersheds that provide it, impacted by beetle kill and the chemicals meant to mitigate it?

Tiny beetles barely the size of a grain of rice have wreaked havoc on western forests in the United States and Canada during the last decade. An outbreak of mountain pine beetles, *Dendroctonus ponderosae*, has turned whole mountainsides of once-green forests brown, brittle, and dead.

CIRES ecologists James McCutchan (Associate Director of CIRES' Center for Limnology) and Suzanne van Drunick (CIRES' Associate Director for Science) are trying to understand how those changes—and people's attempts to control the beetle outbreak with chemicals—are affecting regional water quality and ecosystems.

Their work is funded by the Western Water Assessment, a joint project of CIRES and NOAA.

"Vegetation in a watershed affects the quality and quantity of water," McCutchan said. "If the pine beetles kill the trees, then one link in a complex system has been taken out. We'd like to understand what that means."

Growing forests intercept some of the precipitation and nutrients that fall within a watershed. Tree and other plant roots pull up water that percolates through soil, and remove phosphorous, nitrogen, and other nutrients. As trees die, more nitrogen or carbon may flow downstream, for example, affecting communities of aquatic algae, plants, insects, and even fish. If more phosphorous flows downhill, McCutchan said, it could affect drinking water quality downstream. Some mountain reservoirs—such as Dillon Reservoir—are required to keep phosphorous below certain levels, and often come close to surpassing them.

When human activities add chemical insecticides to the mix—carbamates or pyrethroids are the key ones used to fight pine beetles—there may be further effects on aquatic ecosystems, van Drunick said.

McCutchan and van Drunick will focus their research in Rocky Mountain National Park, for two key reasons: the park is home to the headwaters of many river basins critical for drinking water in Colorado, and working in the relatively pristine park eliminates some potentially confounding effects—septic systems, for example, which can add nutrients to a system.

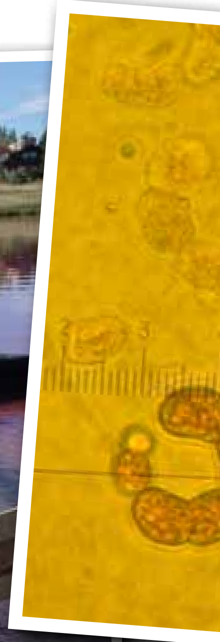
For the pesticide work, van Drunick and her colleagues will collect water samples in the spring of 2010—the peak of the tree-spraying season—from areas immediately downstream of treated trees. The park has focused its limited spray campaign to less-toxic carbaryl, one type of carbamate, in high-priority areas, such as near campgrounds. Homeowners living in scattered private inholdings within the park may also be spraying trees, with potential consequences on aquatic ecosystems.

"Initially, we'll look at areas likely to have the highest concentrations of pesticides," van Drunick said. If the samples show high levels of carbaryl or other pesticides, then she and her colleagues can plan further sampling.

"We certainly don't expect to see enough carbaryl to flat-out kill fish," van Drunick said, "but we can monitor carbaryl to determine if concentrations are high enough to cause sublethal effects such as changes in respiration or swimming performance in fish, or changes in the composition of aquatic invertebrate communities, which could, in turn, affect fish."

McCutchan will measure a suite of nutrients in water samples collected from montane streams in the park during several times of year—including samples from the 2009 and 2010 "Water Blitz," a collaboration with Rocky Mountain National Park scientists interested in monitoring water quality in the park. The single-day Blitz, conducted with the help of dozens of Park Service employees and volunteers, generates a water quality "snapshot in time," McCutchan said.

"We hope that by putting together snapshots with more intensive time sampling, we can go beyond monitoring to analysis, and to understanding the system in a more complete way," he said.



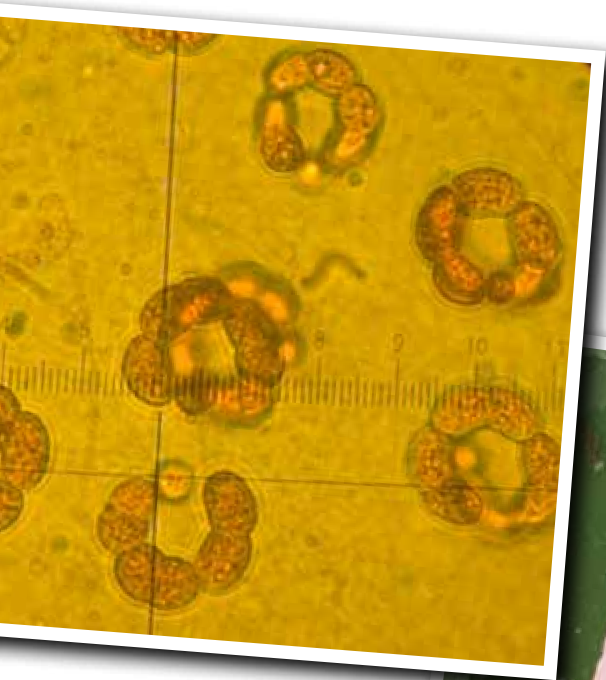
Mystery of the smelly

TheScience

Unpleasant as it may be, the ecology at work in Little Gaynor Lake could have positive implications for biofuel production.

Ah! The sun is shining. The day is warm, and a friendly breeze sweeps by just enough to tease at your hat. On days like these, there's nothing like a nice spring or summer afternoon by the lake. But wait. Something else came in on the breeze, something that doesn't go with good times or fresh air and summer swims. It smells like rotten eggs. And the lake ripples purple across the way, looking like Kool-Aid gone bad.

This is Little Gaynor Lake, a small, naturally occurring basin called a "prairie pothole." The lake is one of two potholes in Boulder County. As ice melts and water warms, the lake periodically turns purple and begins to emit an unsavory odor, an odor that so offended the neighbors that Boulder County Open Space asked CIRES researchers Prof. William Lewis and Dr. James McCutchan to figure out what was going on with this watering hole. The answer might not be welcome news for the surrounding residents, but could bode well for biofuel research.



CIRES photos

purple lake

The source of the dilemma appears to be a natural and rare phenomenon. "As far as we know, there's no overland source of pollution because there's no tributary to this lake," said Dr. Lewis. "So even if there were no people around, the lake would probably still be doing this."

A lake with only a small amount of groundwater flowing through it has become a sulfur-rich environment. With that distinguishing character comes an unusual ecology. Organisms specially adapted to exploit oxygen-poor waters have colonized the lake. An alga, *Anabaenopsis elenkenii*, produces organic matter that uses up oxygen near the lake bottom and leads to the formation of sulfide. One bacterium, *Chromatium*, uses sulfide for photosynthesis and is responsible for the lake's occasional purple color. When wind churns the water, the smelly sulfide rises to the top, and, coupled with light, fuels photosynthesis by the purple-colored bacteria.

That the unusual lake is natural raises uncertainty about what, if anything, Boulder County should do to fix it. The upside is that the organisms responsible for the smelly, purple lake could offer clues to a new form of biofuel production. The alga is hardy, continuing to grow and release energy even in environments deprived of light and oxygen. That makes it a good candidate for biofuel.

The fact that the alga is so abundant is another plus. The theoretical cap on chlorophyll concentrations, an indicator for algae densities, for a lake of this size is about 300 mg/L. Little Gaynor Lake showed concentrations upwards of 2,000 mg/L. "When we saw that we said, 'Wow!' We haven't seen concentrations that high before," said McCutchan.

Need another reason to like this odorous environment? The alga's affinity for salty waters could aid biofuel production in places where agriculture is otherwise off-limits.

On the wing and listening for waterfalls

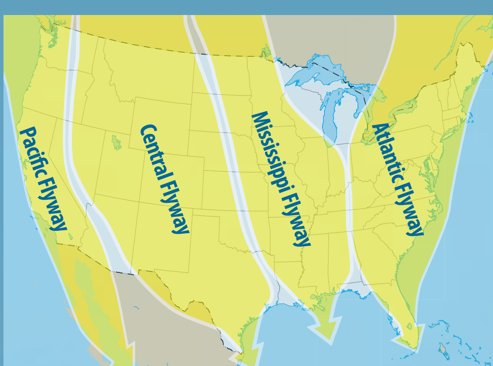
Migrating birds could put the most state-of-the-art GPS to shame with their arsenal of built-in navigation sensors. These frequent flyers use tools, such as Earth's magnetic field, the sun's orientation, visual cues, and weather to navigate migration routes sometimes spanning thousands of miles and multiple continents. Now a new study in progress looks at the possibility that waterfalls might offer another clue as to how birds stay on track. Waterfalls send out distinct sound signatures, so CIRES and NOAA/ESRL scientist Alfred J. Bedard is comparing the soundscape of Niagara Falls with the hearing power of pigeons and migration patterns of birds traveling along the Atlantic Flyway. If Bedard's suspicions prove correct, this would be the first evidence that birds use waterfalls as navigation beacons while on migration.

TheScience

New research suggests that birds use their hearing in addition to solar orientation, weather, and visual cues to navigate migration routes.

North American flyways

There are four major geographic routes along which birds migrate north and south over North America.



CIRES/migration.pwnet.org

iStockphoto

Mapping the seafloor aids tsunami, coastal ecosystem monitoring

For map lovers, digital elevation models (DEMs) are the perfect virtual exploration tool. Zoom in to Alaska's King Cove to see how the sea floor drops off just south of the island. Pan over to the Gulf of Mexico to check out the shallows west of Florida. These maps don't just allow for detailed tours. For a couple of years, researchers have used DEMs to monitor tsunami impacts. Now, they're also helping scientists keep an eye on the health of ecosystems.

TheScience

Maps of the sea floor used to predict tsunami impacts also prove useful in monitoring ecosystems.

CIRES researchers and colleagues with NOAA's National Geophysical Data Center have spent the last few years producing 10-meter resolution DEMs of dozens of coastal areas around the country, from Hawaii to Maine.

"These are primarily for tsunami mitigation, to serve forecast and warning programs," said CIRES' Barry Eakins, science lead of the Coastal Science Team producing the models. NOAA's Lisa Taylor directs the team. Emergency managers trying to plan for potential tsunami inundation events need precise elevation information, she said.

"DEMs can also be used for ecosystem modeling, to predict storm surges associated with hurricanes, to understand coastal upwelling, and to characterize fish habitat," Eakins said.

To produce the technical models, Eakins, Taylor, and colleagues use every source of elevation data available—recent data from sophisticated remote-sensing instrumentation on satellites, airplanes, or boats; or from historic maps produced by federal, state, and local institutions. DEMs are used operationally, in NOAA's Tsunami Forecast and Warning System, and they're beginning to reach ecosystem managers.

CIRES graduate student Jason Caldwell is using DEMs for his Ph.D. research on salmon in the Central Valley Project of California. Caldwell, whose advisor is CIRES Fellow Balaji Rajagopalan, said the project's overall goal is to improve the decision-making tools relied on by water resource and fisheries managers in the Sacramento River Basin, to reduce fish mortality from higher stream temperatures in summer months.

In 2004, the National Marine Fisheries Service identified limitations in the region's water allocation decision-support systems. Water managers had insufficient information about stream temperature fluctuations in space and time (warm stream temperatures are harmful to fish, but streams can be cooled with controlled releases from dams). So Caldwell is linking fine-scale DEMs of the region to hydrology and weather models to better understand when and where water temperatures are likely to exceed critical thresholds for fish mortality. In theory, his work building better decision-support tools can be applied in other locations as well.

Photos/NOAA

An unmanned aircraft system (UAS) is launched from a ship in the Arctic.

Where's Waldo…the seal?

CIRES researcher helps ecologists with pioneering technology

Field biologists tend to collect fascinating stories. The time a gorilla charged. The time someone stepped on a wasps' nest. That harrowing flight to the research station.

It can be difficult to keep tabs on living things, particularly when they live in very remote areas, yet doing so is often critical for conservation decisions. CIRES scientist Betsy Weatherhead is helping NOAA use unmanned aircraft systems (UAS), originally developed for military use, to meet NOAA's mission involving ecology of ice seals in the Arctic.

The seals—ringed, ribbon, spotted, and bearded—all fall under NOAA's protection, and they each rely in some way on floating patches of sea ice—for breeding, foraging, or to escape predators. That makes the animals potentially vulnerable to climate change, which is whittling away at Arctic sea ice. And it makes the seals difficult to study, Weatherhead said. "Seals occur over vast areas of the Arctic, and accessing these areas safely is challenging using current vessel-based and aerial survey technologies."

TheScience

Physicists and ecologists team up to use unmanned aircraft to study remote Arctic ice and the creatures that call it home.

So Weatherhead and several other NOAA colleagues, including Robyn Angliss, Deputy Director of NOAA's National Marine Mammal Laboratory in Seattle, Washington, spearheaded the development and support of a project to send a UAS over sea ice, to see if the technique could be used to identify ice seals and monitor populations.

In May and June of 2009, years of planning culminated in the launching of a Scan Eagle UAS, with a 10-foot wingspan, from the NOAA vessel *MacArthur II* in the Bering Sea west of Alaska. The UAS, which is owned by the University of Alaska-Fairbanks and operated by Greg Walker, carried a video camera and a digital still camera, which captured about 25,000 images during 10 flights over sea ice in the Bering Sea.

Viewed from 300 feet above the surface, a ribbon seal can look like a shadow, or a puddle of dark water on a light-colored floe of ice, and the sheer number of images that require processing is daunting. Now, Weatherhead and her colleagues are trying to figure out how to quickly and automatically retrieve data from the images they obtained.

They're beginning to talk with image processing companies—groups that write face recognition software, for example—to help pick out seals from shadow.

The researchers have pored through enough of the images to know that they will be useful, Angliss said. "We have been impressed by the quality of the digital still images," said Angliss. "Based on preliminary review, we can determine ice seal species, relative age, and gender for some ice seal species. This technology may be useful in the future to monitor ice seal populations across the Arctic."

Occasionally, it's possible to learn even more about the seals' environment. "In some images collected using UAS in other parts of the Arctic, you can see the footprints of polar bears," Weatherhead said. Weatherhead, an atmospheric physicist who studies climate change and variability, especially in the Arctic, said she's delighted to be working closely with population biologists on the project.

"Here we have ecologists counting animals and physicists studying sea ice in the same places," Weatherhead said. "It's terrific to be working together on these same images."

Two seals among the cracks and shadows on the sea ice. NOAA

TheScience

The pernicious chemical pentachlorophenal, or PCP, is still widely used to treat wood for telephone poles or railroad ties. Can an enzyme be engineered to reduce PCP's environmental impacts?

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Evolving a speedy microbe to clean up a chemical mess

Few bacteria would choose the hazardous man-made chemical pentachlorophenol (PCP) from the menu of microbial delights. But one "bug" is giving it a shot. It's the best-described of only a handful of bacteria known to break down the pollutant. One problem though: it's not particularly good at its job, yet.

There's a chance that modern science could help this microbe sort out its digestive problems. That's why CIRES Fellow and Professor of molecular, cellular, and developmental biology Shelley Copley is leading a research team aimed at engineering a more efficient form of the bacterium. "The goal is not just to make a better bug, but to understand what it took to make it happen," said Copley. "How do you evolve new enzymes and new metabolic pathways? We want to understand the process on a molecular level."

If Copley can do that, PCP, long considered difficult to destroy, may have reason to start shaking in its chlorine bonds. Introduced in 1936, PCP worked as an herbicide, algicide, fungicide, and insecticide, and was a widely used wood preservative and disinfectant until it was largely banned in the United States in 1987. Today it's used for mainly industrial tasks: to make utility poles, railroad ties, and wharf pilings last. Exposure to high levels of PCP can induce fever, damage the liver and immune system, and possibly cause cancer. Because PCP is both highly chlorinated and man-made, it is difficult for nature to clean up.

One natural exception is the bacterium *Sphingomonas chlorophenolicum*, which likely developed its pathway for breaking down PCP in the few decades since the chemical's introduction. The process is cumbersome, requiring several enzymes that run into problems along the way. One intermediate product is even more toxic than the original pollutant and can be harmful to the bacterium. "The enzymes don't do a good job, probably because they just haven't had enough time to evolve," said Copley. "They don't have good control over the chemistry."

Some genetic engineering could smooth out the process. Students and post-docs from Copley's group are cloning the genes that encode the chomping enzymes and putting them into the bacterium *E. coli*. They are using in vitro evolution techniques to generate tens of thousands of variations of the enzymes to identify which ones do the best job. Through this process, Copley hopes to select for better enzymes that can then be put back into the original bacterium. If Copley and her team succeed, *S. chlorophenolicum* may become the PCP-eating champion of the world.

"This is a novel pathway that has evolved very recently, offering a rare glimpse into evolution in action," said Copley. "It represents an exciting opportunity to both study evolution and help solve a human health and environmental problem."

The Vatican City workshop and life beyond planet Earth

In 2009, CIRES Fellow Shelley Copley was among the scientists invited to discuss life and its possibilities outside our solar system during a unique meeting in Vatican City.

This was a gathering to discuss astrobiology. Can you tell us about this relatively new area of scientific study and how you became involved in it?

NASA defines astrobiology as "the study of the origin, evolution, distribution, and future of life in the universe." It's a fascinating interdisciplinary endeavor that brings together astrophysicists, planetary scientists, geologists, chemists, biologists, and even philosophers.

My interest in astrobiology stemmed from my work on the evolution of enzymes and metabolic pathways. Thinking about the origin of the sophisticated protein enzymes and robust metabolic networks found in extant life inevitably led me to thinking about the characteristics of the earliest life forms on Earth, and then to thinking about how they arose from the collection of small organic molecules available on the early Earth.

What was it like giving a talk of this nature in a place like Vatican City?

It was surreal. In many ways, it was a typical scientific meeting. There were excellent talks from top scientists in diverse areas of astrobiology, and fascinating discussions over coffee and meals. Our hosts were priests, but the meeting wasn't about religion, or the relationship between religion and science—it was all about the science. The Vatican has a long history of interest in astronomy. The idea that life might be found elsewhere in the Universe is quite acceptable to the Church, and indeed would be considered as evidence of God's magnificence.

You spoke about catalysts as essential for life to emerge. Can you tell us a little more about this relationship?

Almost every reaction that occurs in living organisms is catalyzed by an enzyme. This is critical for life because these reactions would otherwise be terribly slow. Catalysts were also critical for the emergence of life, not only because they accelerated the rates of certain reactions, but because they dictated the types of reactions that would be incorporated into modern metabolic networks.

Were there any other topics that stood out for you?

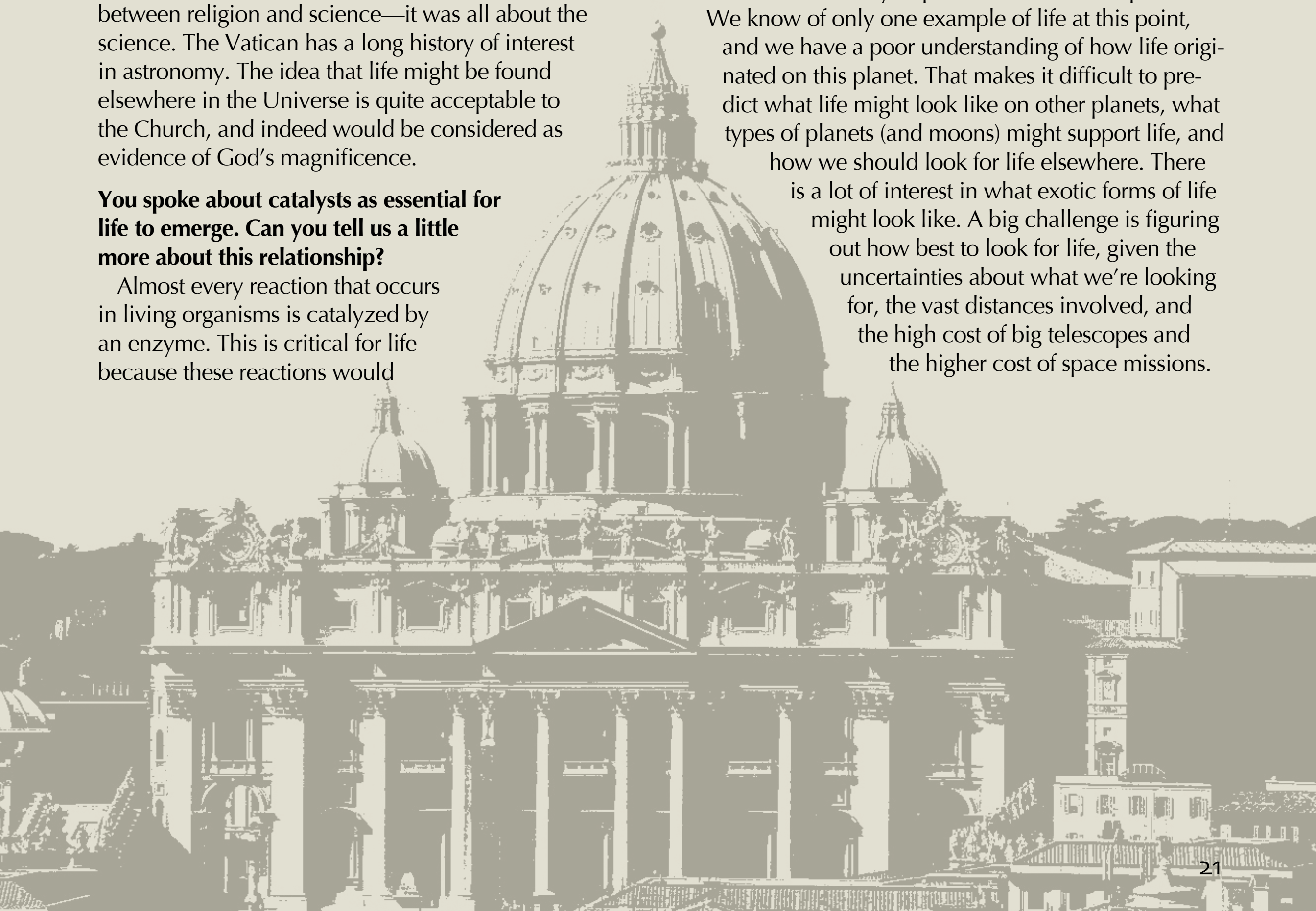
The topic that really grabbed my interest was the amazing increase in the rate of discovery of extra-solar planets—there are now several hundred known extra-solar planets! Also, the ability to detect planets in the habitable zones is improving. This is harder because it requires detection of smaller planets closer to stars, but it is starting to happen, so we can now be sure that there are habitable planets out there.

What did you get out of this experience?

I came away with a renewed sense of excitement about working on a Really Big Question—the origin of life—and a profound respect for the power of interdisciplinary science.

Where do things go from here? Life on other planets? A better understanding of life on Earth?

There are so many important unanswered questions. We know of only one example of life at this point, and we have a poor understanding of how life originated on this planet. That makes it difficult to predict what life might look like on other planets, what types of planets (and moons) might support life, and how we should look for life elsewhere. There is a lot of interest in what exotic forms of life might look like. A big challenge is figuring out how best to look for life, given the uncertainties about what we're looking for, the vast distances involved, and the high cost of big telescopes and the higher cost of space missions.

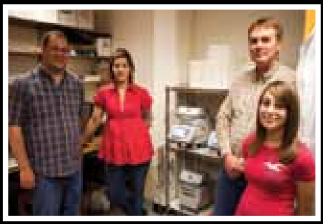


MySphere

How people work, research, and relax at CIRES

1. A vacuum pump—it really sucks.
2. Protocol posted in mid-air so as to be resistant to note-taking.
3. Flammables cabinet—doubles as tiny graduate student office.
4. Timer used to see how long it takes for a) experiment step to finish, b) donuts to disappear.

Fierer Lab



From Left: Chris Lauber, Donna Berg-Lyons, Scott Bates, Ashley Grimaldi

Why are microbes cool?

"Because they're like tiny little people!" —Gaddy

"Because they're everywhere; they're ancient, and 99 percent of described species are unculturable, which means no feeding, no tanks to clean, and no poop to pick up." —Garrett

"Microbes make the world go round, some give us the runs while others give us a buzz!" —Bob

"The immense number of microbes, although individually small, affect chemical cycles on a global scale." —Chris G.

"Because there aren't many things that can produce both cheese and diarrhea." —Chris L.

"They've ruled the world for billions of years, and they're incredibly diverse, but we've only just begun to crack their secrets." —Kate

Morgan Heim/CIRES

5 Polymerase chain reaction (helps look at DNA) cleanup kit with components missing to provide additional fun when working under deadlines.

6 The bar—helps make the "cocktail" reagents for samples.

7 Multichannel pipette for measuring out samples.

8 Tip jar for used micropipette tips—fills up in less than five minutes, sometimes even faster when Donna's well-caffeinated.

9 Assistant Ashley blending in with lab equipment.

10 Sample wells—where thousands of little DNA's live. Equals $5,000 in samples and one Ph.D. disseration (no joke).

11 Latex gloves stuffed back in box after failed attempt to "get the prize inside." Used to prevent contamination.

CIRES

The Cooperative Institute for Research in Environmental Sciences is a research institute dedicated to better understanding the Earth system.

Our research is essential for understanding the processes and feedbacks in many Earth science disciplines, and to foster cross-disciplinary understanding of the cryosphere, biosphere, atmosphere, geosphere, and hydrosphere. CIRES scientists are identifying and quantifying changes in a warming climate, providing baseline data against which to measure change, and informing the public and the policy makers about these changes.

CIRES is a cooperative institute of the University of Colorado at Boulder and the National Oceanic and Atmospheric Administration.

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