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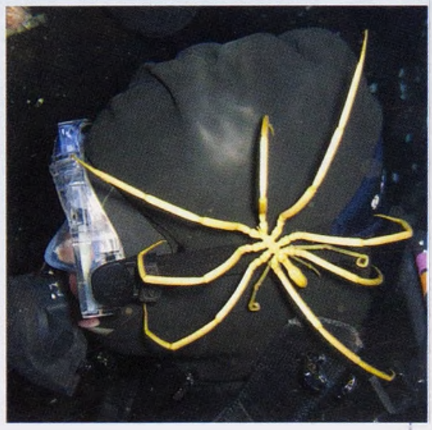
Living Large in Antarctica

Scientists study polar gigantism

UM's Art Woods waits for Friendly the Weddell seal to vacate a dive access hole in Antarctic sea ice. (Upper right) A common nudibranch in McMurdo Sound. (Bottom right) A large sea spider placed on the head of researcher Amy Moran.

Photos by Chris Shields (seal), Jon Sprague (nudibranch) and Bruce Miller (sea spider).

Friendly had become a problem.

Every time University of Montana researcher Art Woods and his colleagues dove under the Antarctic ice at one of their main collecting sites, Friendly was there. The 1,000-pound Weddell seal shadowed them like a finned blimp as they hunted nudibranchs – strangely beautiful sea slugs – as well as egg masses and other specimens.

Sometimes Friendly would shoot off into the gloom for 10 minutes or more, but he never strayed far. He would return with eerie vocalizations that sounded to Woods like a movie flying saucer coming in for a landing. A few times Friendly surfaced in their dive hut placed atop an access hole drilled through a dozen feet of sea ice. The seal would float like a cork, take a nap, fill the hut with his fishy breath and then inhale deeply before swimming on.

The divers enjoyed Friendly at first. He added magic to Antarctica's 28-degree water world of fish, worms, jellies and centuries-old sponges – all roofed in frozen white. And despite their size, Weddell seals are docile and rarely hostile to humans.

Of course they can still cause problems. Near the end of one dive, the researchers returned to their access hole to find tail flippers hanging down and Friendly's vast cylinder of blubber plugging their only escape route to the surface.

The divers were cold after being submerged for 35 minutes. What to do? People working at the U.S. science base on McMurdo Sound aren't supposed to bother local wildlife, but Friendly seemed in no hurry to move.

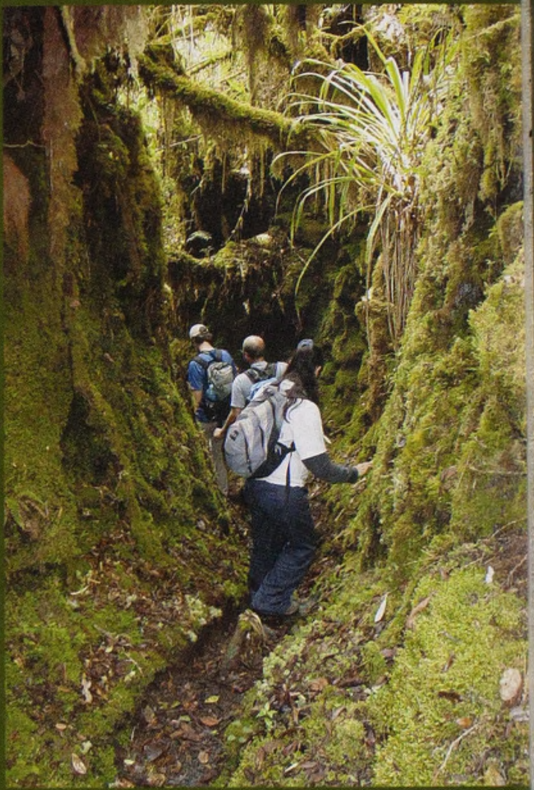
After several long minutes giving one another "Now what?" looks, the divers tried sending air bubbles up the access hole to rouse Friendly. Weddell seals are supposedly skittish, but Friendly didn't budge. Finally, growing worried, they tugged a tail fin.

"Instead of scattering, he just came down the hole and floated up right under the ice to watch us," Woods says. "It was like he said, 'OK, you can go now.' Whew!"

That was one of many I'm-not-in-Montana-anymore moments Woods experienced while working in Antarctica supported by National Science Foundation funding. He went to the bottom of the world during October and November (the Antarctic spring) 2006 and again in 2007. He did 25 dives in 2006 and 35 last year. A primary goal: learn how water temperature affects animal metabolic systems.

Woods, an assistant professor in UM's Division of

Antarctica – continued back page



All photos by Erick Greene except jaguar imag

(Top) UM and Peruvian college students explore high-elevation grasslands in the Andes. (Upper right) Classmates descend a sunken jungle path. (Bottom right) Students use dugout canoes in a swamp near the Madre de Dios River.

Andes to Amazon Adventure

UM offers remote South American field course

Descend 8,000 feet from the top of the Andes to the Amazon Basin in one nine-hour hike. Travel up one of the most remote rivers on Earth. Encounter some of the planet's rarest wildlife. Conduct research alongside some of the world's best tropical ecologists.

Sound like adventure tourism? Think again. These amazing opportunities became a reality, not for tourists, but for a lucky group of UM and Peruvian students taking part in a new Peruvian Tropical Biology course offered by UM's Division of Biological Sciences.

The course was the brainchild of Alex Trillo, a UM doctoral student. A native Peruvian, she received her undergraduate degree in biology at the University of California, San Diego.

"While I was there, I helped with several field courses that took UC students to Costa Rica," Trillo says. "We learned the biology, but I felt the students were missing a lot."

What they were missing, Trillo says, was interaction with their peers in the host country and immersion in the country's culture and language. She would soon be in a position to change that.

After moving to Missoula, Trillo heard about a Harvard graduate-level class where students conducted research with local biologists in Belize. She and fellow graduate student Andrew Whiteley thought they could organize a similar course at UM and approached biology Professor Erick Greene with their idea. He enthusiastically agreed to help organize and teach the course, as well as find funding.

The trio quickly set goals for themselves. They would teach a semester-long seminar course on tropical biology and conservation for 10 to 20 UM students. They would establish ties with corresponding universities in Peru, where qualified students would be selected to participate. Most important, they would organize a four- to six-week intensive field course where UM and Peruvian students would conduct research together in some of the most remote and biologically diverse hot spots in Peru.

That was the start of fall semester 2004. By the following January, Trillo, Whiteley and Greene were in Peru making preparations. They discussed the course with the chancellor and faculty members of the Universidad Nacional Agraria La Molina in Lima, who agreed to participate, and they visited research stations and field sites, arranging buses, boats, planes and the necessary government permits.

By spring semester 2005, the course was under way. UM students enrolled in the seminar class to prepare for the field trip. An equal number of students in Peru were selected, and in August both groups met in Lima for what was to be the trip of a lifetime.

From Lima, the group flew to southeastern Peru and made its way to the cloud forest, high in the Andes, to a remote research station called Wayqecha. The cloud forest is one of the most poorly understood ecosystems in the world, and the group stayed several weeks to study it. From Wayqecha, the students made their way to the crest of the mountains and began an epic hike from high-elevation grassland habitat down to lowland rainforest – a drop of 8,000 feet. In the process, they traversed four life zones (distinct sets of habitats characterized by specific temperatures, rainfall, altitude and species) on trails where the vegetation literally grew over their heads. Once in the lowlands, the group took boats up the Madre de Dios River to the Los Amigos Biological Station, the last field site on the trip.

The students conducted rigorous research in Peru, and there could hardly be a better place for it. Peru is one of the most biologically diverse places on Earth. While Montana's Clark Fork River supports about 25 species of fish, the Madre de Dios River may have as many as 250. Fully one-quarter of bird species on Earth live in the relatively small part of Peru the group visited.

The students were introduced to this mind-boggling diversity with daily field trips and taxonomy workshops led by instructors and research station staff. They learned about reptiles, amphibians, fish, mammals, insects and birds in each area they visited and about the research tools used to study them. Students also attended short lectures and classes in the evenings, as well as informal conservation talks on threatened Peruvian national parks. They conducted their own research, both individually and in groups, and presented their results throughout the trip.

Greene says interaction and cooperation between the U.S. and Peruvian students was key to the trip's success.

"We didn't want two cliques of students, one U.S. and one Peruvian, working in isolation," he says. "We wanted them to interact and learn from each other."

One medium for this interaction was language. The course organizers saw to it that a few of the U.S. students spoke Spanish and a few of the Peruvian students spoke English. Since the instruction was in both Spanish and English, the students were constantly translating for one another. The students' complementary perspectives on science also brought them together.

"Biology students in the U.S. are trained in experimental design and hypothesis testing, as well as the theoretical bases of ecology, genetics and statistics," Trillo explains. "In contrast, Peruvian biologists are more grounded in taxonomy, systematics and natural history. When you combine these two areas of expertise, there is an explosion of knowledge."

"The level of student interaction and learning that occurred went beyond my wildest dreams," Greene says. "For instance, the U.S. students gained a broader perspective on Peruvian conservation and learned that it was necessary in Peru to balance economics, native issues and a burgeoning population."

By their own accounts, the U.S. students felt the course was life-changing, and many expressed the desire to return to the tropics and work to protect the region.

For the Peruvian students, the course provided more research and career opportunities than they ever thought possible.

"Many have gone on to do things they absolutely wouldn't have done before taking this course," Greene says. One student, for example, won a prestigious grant from the Missouri Botanical Garden to continue research she started during the trip. Another became a course instructor and the head of research management for the Peruvian branch of the World Wildlife Fund.

Thanks to the generosity of alumni and the enthusiastic support of the UM administration, Peruvian Tropical Biology has now been offered twice with great success.

"We hope to develop long-term commitments and funding for the course, which is the only one of its kind that we know of," Greene says. "It's expensive and time-consuming to organize, but its impact on students is incredible."

As Trillo puts it, "Both U.S. and Peruvian students have benefited tremendously from this course. If conservation is to be truly global, we will need scientists who have had exactly these kinds of cooperative experiences."

– By Anne Greene

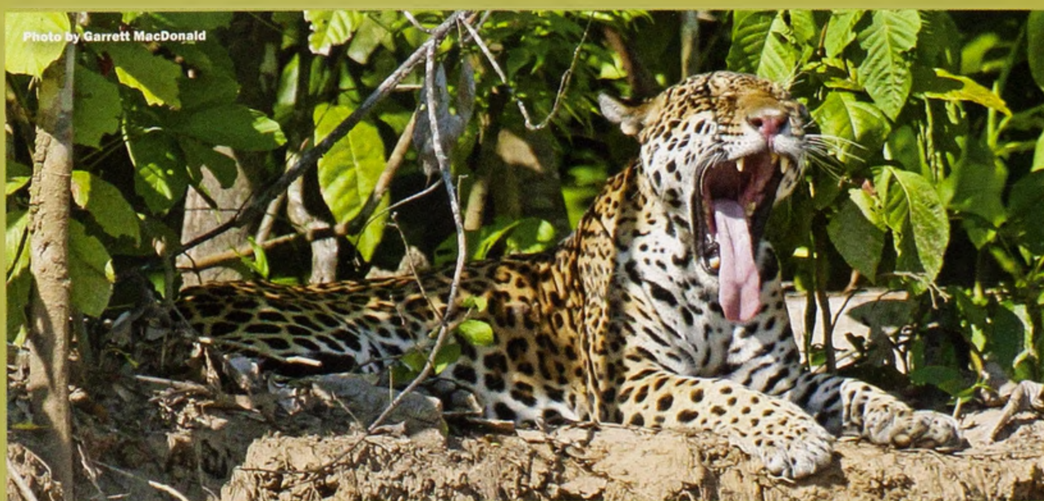


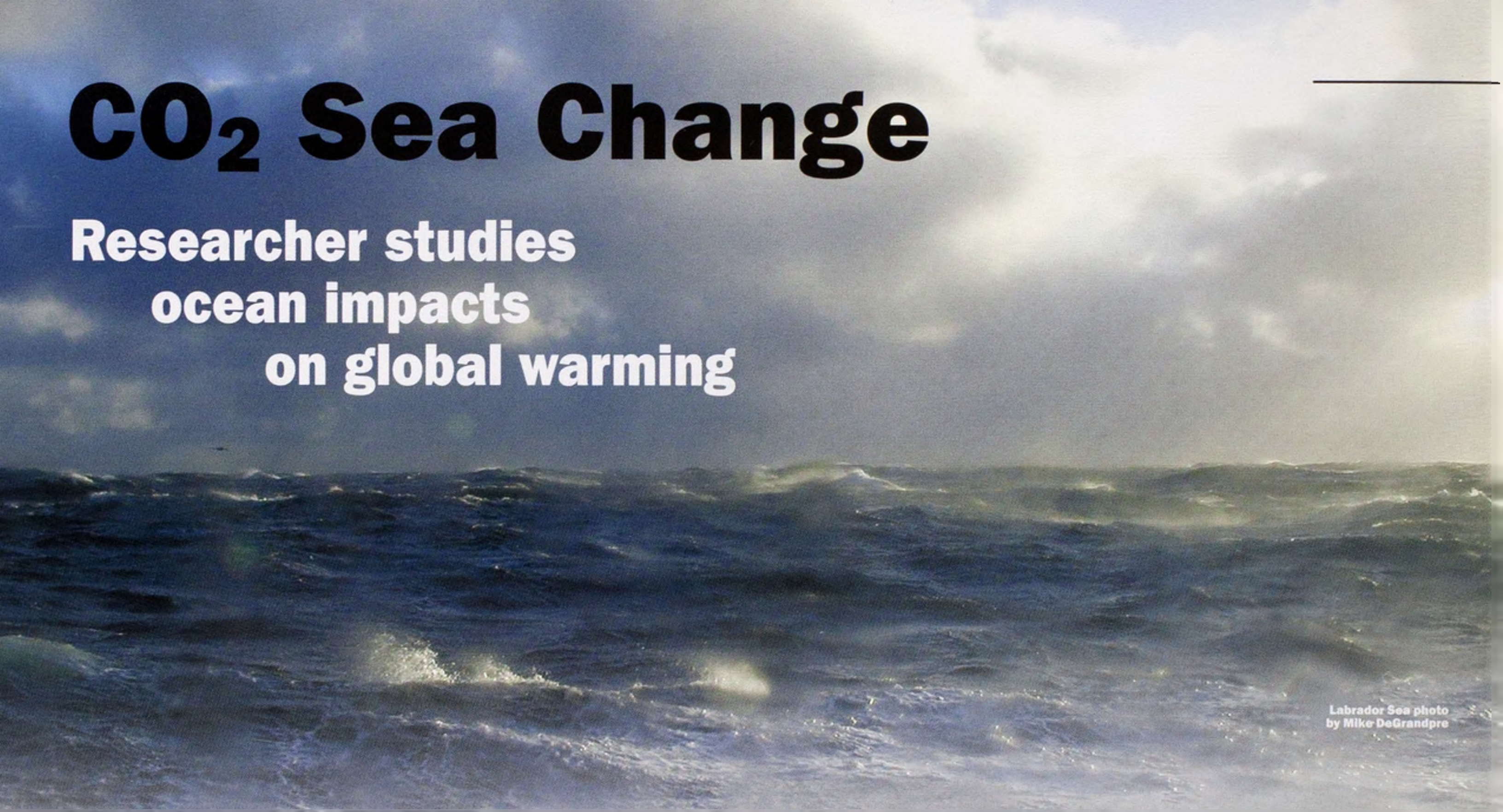
Photo by Garrett MacDonald

Students got up close and personal with many unusual Peruvian creatures: (Top) A rarely seen jaguar lounging on a riverbank. (Middle) A brightly colored motmot. (Far right) A giant tree frog.

(Bottom left) Students hold an assortment of giant seed pods.

CO_2 Sea Change

Researcher studies ocean impacts on global warming



Labrador Sea photo by Mike DeGrandpre

Scientists taking on the growing threat of global warming and climate change are faced with two monumental challenges: how to accurately predict the future; and, given that, how to change the future.

For nearly two decades, those fundamental goals have guided the research of Professor Mike DeGrandpre, a UM oceanographer and analytical chemist.

Landlocked Missoula, Mont., hundreds of miles from the nearest sea, might seem an unlikely place to find an oceanographer, especially one as highly respected as DeGrandpre. His research into the Earth's marine-carbon cycle and his related technological innovations are helping scientists throughout the world understand the role of oceans in climate change caused by increasing accumulations in the atmosphere of greenhouse gases such as carbon dioxide.

Since 1990, the specific objective of DeGrandpre's research is to determine how oceans absorb CO_2 from the atmosphere.

He says that studies indicate "oceans have taken up 25 to 30 percent of CO_2 pumped into the atmosphere by fossil fuel combustion and biomass burning by deforestation.

"Assuming that CO_2 in the atmosphere is causing global warming," he adds, "we pretty much know that the oceans have reduced the impact of greenhouse gases. Levels would be 25 to 30 percent higher in the atmosphere if not for the oceans."

Through research such as his that seeks to comprehend the oceans' mechanisms for taking up CO_2, DeGrandpre says, scientists hope to more accurately predict the future, and then try to mitigate climate change.

So far, there are more questions than answers.

"With our warming climate," he says, "how does that feed back into these processes that take up CO_2? Right now we don't know if it will have a positive or negative impact. So, as the oceans warm, will they have reduced capacity for taking up CO_2 or a greater capacity? We still don't know the answer to that."

To find the answers, DeGrandpre invented an innovative research tool that measures the amount of dissolved CO_2 in oceans or other bodies of water.

Mike DeGrandpre checks a sensor before deployment.

Dave Hebert photo

The device – called a Submersible Autonomous Moored Instrument, or SAMI-CO_2 for short – is a plastic cylinder about 6 inches wide and 2 feet long. They are self-powered and capable of hourly measurements for up to one year. All data collected is logged to an internal memory chip to be downloaded later.

These sensors usually are placed a few feet underwater on permanent moorings, while others on floating drifters sample the water wherever the wind and currents carry them. The instruments have been used by researchers around the globe in a variety of studies since 1999.

DeGrandpre developed the SAMI from 1990 to 1993 during his postdoctoral work at the Woods Hole Oceanographic Institution on Cape Cod, Mass. He's continued to make incremental improvements to the sensor since joining the UM faculty in 1996.

In addition, he created a spin-off company, Sunburst Sensors, to manufacture, market and provide technical support for SAMIs sold to other researchers. He then teamed with Missoula businessman and mechanical engineer Jim Beck, and the company's sales and service have totaled $1.2 million from late 1999 through December of last year. The business employs one undergraduate student, two engineers and one postdoctoral research scientist.

Interest in DeGrandpre's research using SAMI technology, he says, has generated $400,000 in grants to

Sunburst from organizations such as the National Science Foundation to encourage commercial development of the system so other scientists can benefit from it.

"The science community knows I publish good, quality (research) papers," DeGrandpre says. "That gives Sunburst credibility."

Sunburst recently received two new grants, including $900,000 from the National Oceanographic Program, to improve the reliability of the SAMI system, which has been a problem for the company. A new model has been extensively tested in the laboratory, and a prototype will be tried at sea this year. DeGrandpre says he expects the new sensor to be in production later in 2008.

"We've never advertised (SAMIs) because we've been dealing with a non-user-friendly instrument," he explains. "So our goal was to redesign it and market it. At that point, we could really take off. Now technical support drains the company. Also, if they don't work, we get a bad reputation.

"We now have about 50 or 60 of these instruments out there. We can handle that level, but not more. We hope, with the new design, it will be just sort of plug-and-play. We could really sell a lot of those things."

In addition, Sunburst has developed and started to market a new pH sensor and a novel method for measuring alkalinity, he says.

While developing the alkalinity sensor, DeGrandpre and his research group discovered a new method of titration – a standard chemical measuring technique – that immediately generated commercial interest.

The new system uses tracer chemicals, he explains, which eliminate the need to have accurate volume measurements as a prerequisite for chemical analysis.

"It's sort of like developing a new way of slicing bread," he says. "Sometimes you do something, and you say, 'Why hasn't someone done this before?' This was surprisingly simple."

The SAMI pH technology relates to DeGrandpre's recently expanded research focus into ocean acidification and the possibility of increasing the ability of the oceans to take up more CO_2.

"It all relates to CO_2," he says. "So the oceans are taking up all this CO_2. But the CO_2 forms carbonic acid like in Coca-Cola. The pH drops from that. That's called acidification of the oceans.

"What's that going to do to all the animals that form calcium carbonate – or shells – from the CO_2 in the water? As pH drops, their ability to form shells is diminished, or impacted, because calcium carbonate solubility goes up as pH goes down.

"Here's an example," he adds. "Everyone around (Missoula) gets calcium carbonate buildup in their sinks, because we have relatively hard water. And we use an acid – lime – to dissolve it. Basically, we're liming away our oceans with CO_2. It has impacts on food webs and coral reefs."

That's a concern of scientists in the fertile ocean off the southern tip of South America, according to DeGrandpre, who was involved in an extensive research voyage on those seas from Feb. 28 to April 9 this year.

While DeGrandpre wasn't on board the research vessel, his SAMIs are crucial to the mission, funded by the National Oceanic and Atmospheric Administration, as well as the National Science Foundation and NASA.

Sensors employed by other scientists on the research mission – studying a wide range of factors relating to CO_2 exchange – were connected to DeGrandpre's SAMI drifter system. The sensors were suspended on cables like tentacles of a jellyfish at varying depths up to 100 meters.

The drifters contain a global positioning system transmitter that allows the ship to locate them and retrieve their stored data after days of sampling the ocean.

"Our system is the main brain, collecting all the data from the sensors connected to it at various depths," DeGrandpre says. His own studies of CO_2 exchange and ocean pH are being conducted in collaboration with other scientists on board.

Theoretically, he says, the ocean's capacity to take up CO_2 could be increased by fertilization.

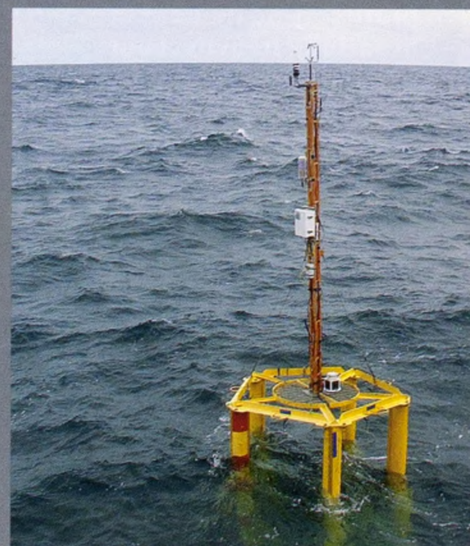
Our ability to change the future of climate change could be accomplished in various ways, he says, including switching to alternative energy sources and stepping up conservation efforts. Or, he suggests, it might be altered through engineering processes like sequestering carbon by fertilizing the oceans, resulting in increased plant productivity, which would allow oceans to take up more CO_2 through photosynthesis.

"But what would be the effect on the food web?" he asks. "A lot of different calculations have widely different interpretations of the results of fertilizing the ocean. Right now we don't understand the systems enough to tell if it would be a benefit or not. Some impacts are not foreseeable. That's the reason for the research."

– By Daryl Gadbow

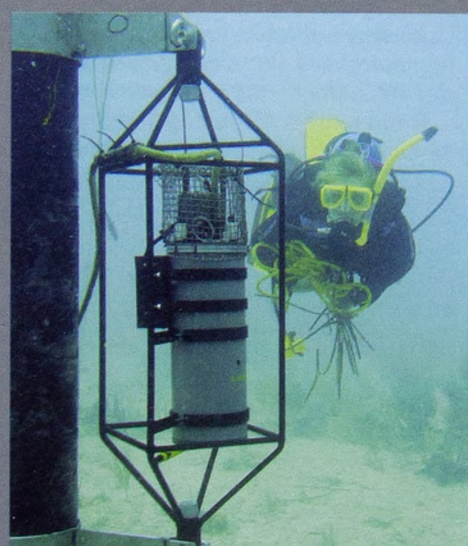
Mike DeGrandpre photo

A research vessel in Chile that released UM sensors near Antarctica.



Cory Beatty photo

A SAMI-CO_2 sensor is attached to this floating buoy in the Labrador Sea.

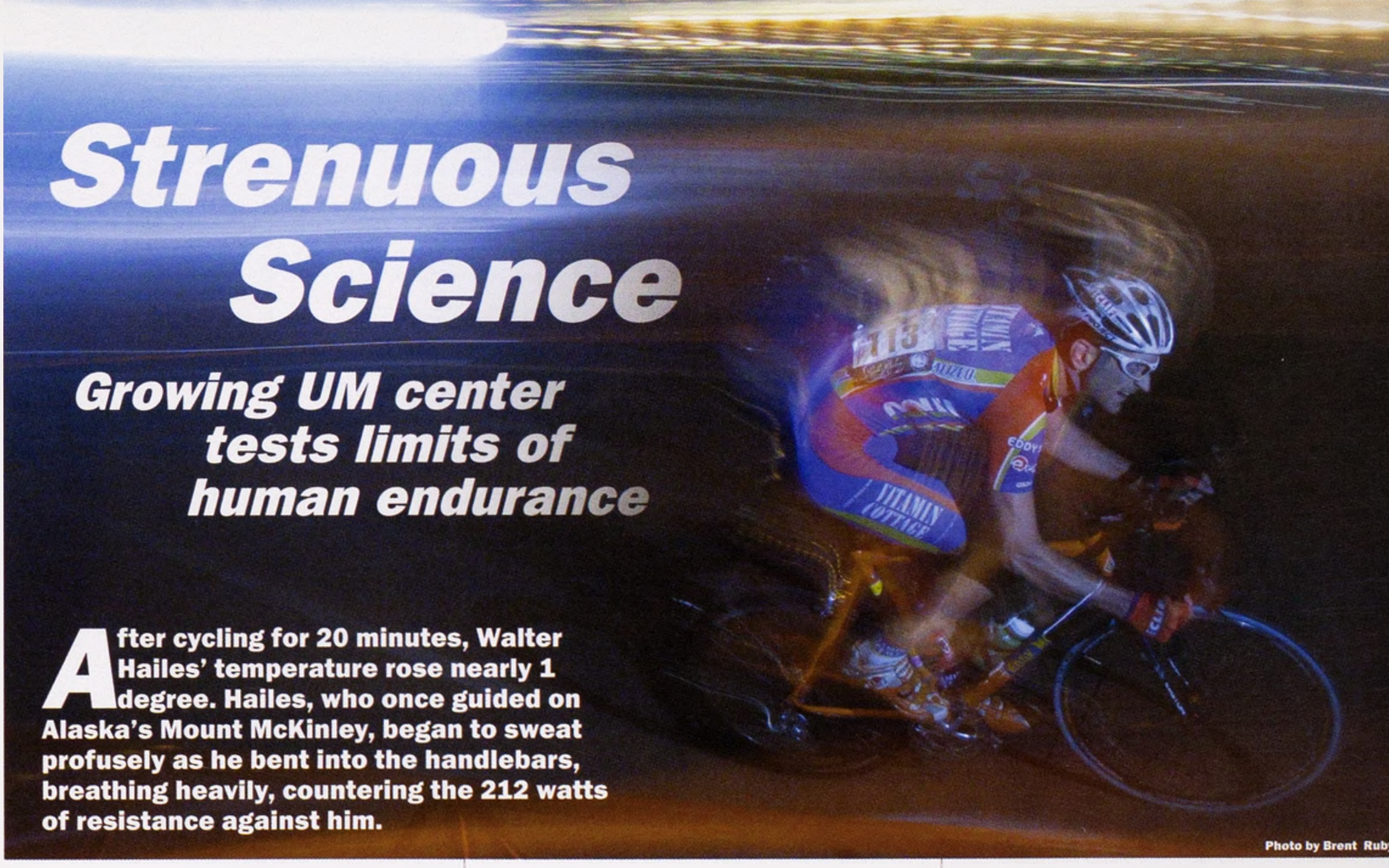


Jim Hendee photo

A UM sensor deployed near a coral reef in the Bahamas

Strenuous Science

Growing UM center tests limits of human endurance



After cycling for 20 minutes, Walter Hailes' temperature rose nearly 1 degree. Hailes, who once guided on Alaska's Mount McKinley, began to sweat profusely as he bent into the handlebars, breathing heavily, countering the 212 watts of resistance against him.

Photo by Brent Ruby

Only through one-third of an indoor low-intensity bike workout, Hailes felt like he was working harder than that. Despite the winter weather outside, he cycled in a 90-degree "hot box" that felt like a July afternoon in Montana.

"Once his temperature hits 39 degrees (Celsius), he's going to get a lot more uncomfortable," says Brent Ruby, the director of UM's new Montana Center for Work Physiology and Exercise Metabolism.

The center, awarded a federal grant in 2006, studies the limits of human performance in harsh occupational environments. The experiment Hailes tested was part of a graduate thesis studying how the body recovers from strenuous activity in heat and is representative of the center's research methods, which mimic real-life settings.

Three rounds of funding from the U.S. Air Force Research Laboratory, scheduled until 2009, will potentially give more than $4 million to the center. In April the facility will move to a 5,000-square-foot renovation under construction at the southeast corner of McGill Hall.

Ruby and his team seek to define how much the human body can endure and use those results to ensure safety and performance in tough work environments such as special military operations, wildland firefighting and ultra-endurance settings. Researchers will try to find solutions to fatigue, overheating and other risks. Their results may offer changes in training procedures or supplemental feeding regimens.

"If we know more about the human ceiling for heat stress, energy expenditure and everything in between," Ruby says, "we can really have a better influence on serving the needs of the Air Force Special Operations Command, other military operations and the wildfire fighters."

Ruby has studied wildfire fighters since he began working at UM in 1994 as an assistant health and human performance professor.

Wildland firefighters are a crucial research subject – especially after a decade of intense fire seasons. Ruby found they can shed up to eight liters of water over 24 hours and burn 4,500 to 6,500 calories – the equivalent of eating eight to 12 Big Macs per day.

Wildland firefighters risk overheating, overworking and mental lapses, Ruby says. He found that special military operations forces are subject to similar risks.

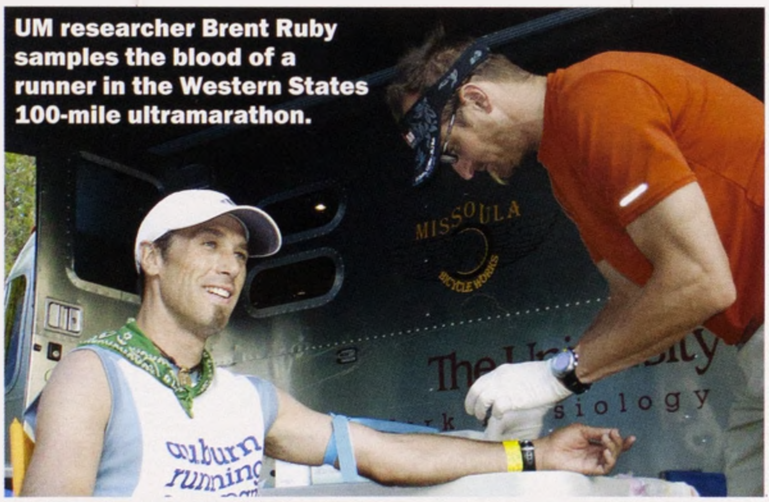
Because military maneuvers cannot be studied in the field, the center uses wildfire fighters, military personnel during training exercises and, in some studies, ultra-endurance athletes as research models.

"The potential to get overheated

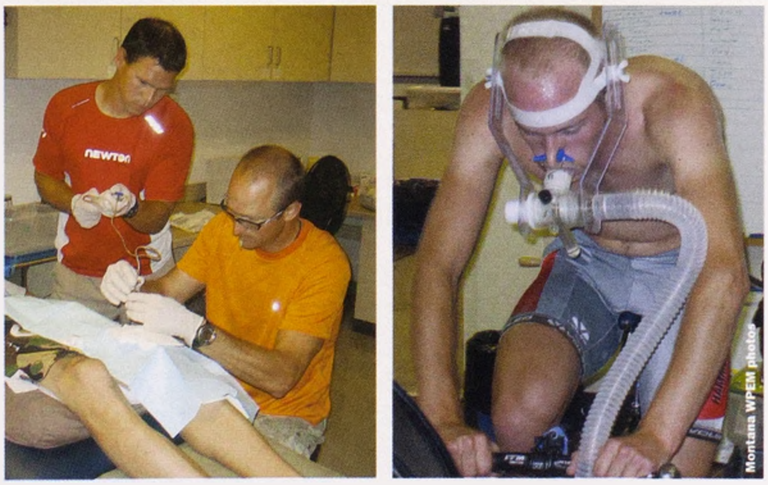
U.S. Air Force photo

National Interagency Fire Center photo

The UM center studies hard-working groups such as U.S. Air Force special forces (left) and wildland firefighters.



UM researcher Brent Ruby samples the blood of a runner in the Western States 100-mile ultramarathon.



(Left) Ruby and muscle sample specialist Dusty Slivka extract tissue from a leg. (Right) A subject on an exercise bike completes in-lab testing before a 2,000-mile cycling study.

is huge; the potential to go into that situation underfed and to stay underfed for that period of time is commonplace," Ruby says. "If you're going to keep someone safe in an operationally hazardous or hostile world, you have to be able to figure out a way to study that."

Col. Jim Wright, an AFSOC flight surgeon for 22 years, visited UM in 2003. He spoke with Ruby and others about his department's research needs. About half of AFSOC recruits drop out of the two-year "training pipeline," Ruby says, so the center is trying to find ways to keep men in training while also considering their unique needs in combat.

Special operations forces often immediately go into action carrying all of their gear. This can amount to carrying 120-pound loads in extreme environments. Staying alert and consuming adequate food and water can be a challenge while working in desert temperatures that can reach 120 degrees or climbing in regions with altitudes of 8,000 to 12,000 feet or more above sea level.

Research that applies to special forces operations means more than just success in combat. The men on duty, Wright says, are sons, brothers and fathers. "We have a moral duty to try to train and equip these men as well as possible so they can come back safely and do their jobs well," he says.

UM collects data with paid volunteers at a lower cost than the military, and their research provides complete data that institutions such as AFSOC couldn't collect on their own, Ruby says.

Ruby and his team have made multiple trips to Air Force bases in Texas and Florida to study men in training, perform lab work and present earlier findings made at UM.

Although Wright and AFSOC work with other military units and universities, he says the exchange with UM is their main effort. "You have some unique expertise there that does not exist across the country," Wright says.

After receiving the grant in 2006, Ruby knew his department's Health and Human Performance Lab, which hasn't changed much since the 1950s, had to be updated to support the grant's specifications. Ruby has directed that lab since 1994 and will pass that job to another faculty member when his staff moves into its new renovated center.

The 3,550-square-foot first floor will house a new biochemistry lab and a 10-by-10-foot climate-controlled environmental chamber that researchers can set to different levels of temperature and humidity. The center also has mobile capabilities with its partly solar-powered Airstream trailer.

Ruby's research crew includes Hailes and John Cuddy — both lab technicians — and Dusty Slivka, a muscle sample specialist. In August 2007, they broke in the center's 25-foot mobile lab by studying a group of cyclists biking 2,000 miles through the Rocky Mountains to determine how sustained fatigue affects the human body.

The center strives to find uniquely extreme events to collect rare data. As an example, Ruby and his team soon will study racers in a 135-mile, one-day race across Death Valley.

In the thesis experiment mentioned earlier, a subject cycled on a computer-controlled exercise bike in 90-degree heat for two different hour-long trials, then rested for four consecutive hours in the heat after one trial and in a cooler laboratory after the next.

After the trial, the subject was given a liquid meal, and researchers studied how much muscle fuel they could replenish, Ruby says.

In human research, the center focuses on variables that Ruby calls "the big four" — saliva, urine, blood and muscle. Muscle samples, procured by inserting a 4-inch-long needle slightly smaller in diameter than a drinking straw into the quadriceps leg muscle, are the most difficult to collect. Ruby often has been a subject for research requiring those samples.

Ruby, who just turned 40, competed in the 2006 Ironman World Championship in Hawaii. He couldn't pass up the rare opportunity to provide data before and after the strenuous race. The average Ironman racer sweats the equivalent of eight, two-liter pop bottles and expends 9,500 calories of energy on race day. Ruby contends he is likely the only racer who has captured muscle samples before and after the event.

Recently, Ruby pilot tested the same experiment as Hailes. He lost three and a half pounds during the trial, and his temperature reached 104 degrees during an hour in the hot box — simply a sauna that includes a resistance bike, large fan, medical bench and other equipment.

When renovations are complete, the center will have more advanced equipment, allowing scientists to closely mimic the extreme conditions military personnel and fire crews are exposed to during extended operations.

Although Ruby and his staff may serve as subjects for physically demanding tests, it's easy for them to stay interested in their work. "Where recreation ends and research begins there is a gray area," Ruby says with a smile. "It's hard to know if I'm at work or at play."

— By Ashley Zuelke

Antarctica – continued from front

Biological Sciences, chose nudibranchs to study because they are diverse, occurring in thousands of fantastic varieties around the globe. They also are simple creatures that use reproductive structures called egg masses – basically slug snot embedded with embryos.

Between trips to Antarctica, Woods also studied nudibranchs off the coast of Washington at the Friday Harbor Laboratories.

"We were interested in this latitudinal comparison of how their physiology works," he says. "The idea of going all the way to the end of the Earth is that animals often do really extreme things in extreme environments."

In the case of Antarctic nudibranchs, they get really big. It's a phenomenon called polar gigantism. Woods says cold water contains more oxygen and, more importantly, it depresses metabolic rates, so animals consume oxygen less quickly. This means they actually live more slowly. The same holds true for their egg masses.

"Off the coast of Washington and Oregon, nudibranchs might be babies in the egg mass for two weeks," Woods says, "but in Antarctica they can be inside the egg mass for a year and half. In addition, the babies they produce are 20 to 30 times as large as those off the West Coast. The egg masses are bigger, and the embryos within them are gigantic."

Why? Woods and colleagues are testing the idea that Antarctic species have a much easier time getting oxygen to all their tissues.

"So if you are living really fast and you are really hot, it might be good to be small, because then you can still get oxygen to your middle tissues easily," he says. "If you are living slowly and there is plenty of oxygen around, then you can afford to get really big without suffering from oxygen constraints."

Slow-living nudibranchs move at glacial speeds. Woods says if your collecting bag gets full, you can set one on an interesting landmark and come back during the next day's dive. It will still be there.

Woods' research is complicated by the fact none of his study species occurs in both Washington and McMurdo Sound. So he compares different varieties and then takes into account how closely related they are to one another. This has led to creation of a nudibranch phylogeny – a family tree that describes the evolutionary relationships among sea slug species.

Amy Moran photo

Art Woods on the ice

Woods' main research partner is Amy Moran of Clemson University. One of her graduate students, Chris Shields, has made the phylogenetic tree his research focus, trying to determine how Antarctic nudibranchs are related to those in the rest of the world. If Antarctica is an isolated sea slug outback, then they should be most closely related to their neighbors. However, the genetic work has shown that most Antarctic sea slugs are more closely related to nudibranchs in other oceans. This suggests the southernmost continent has been invaded by nudibranchs many times in the past and that it's not that difficult for them to migrate there.

Woods says his group's genetic research has doubled the number of described nudibranch species in McMurdo Sound to about 16.

"It wasn't our main goal to find new species," he says, "but it's amazing to me that you can go somewhere in the world and – with not much effort – double the number of known species. It's remote there, but you would think in this day and age the fauna would have been sampled pretty well."

Another species the researchers became interested in are pycnogonids, or sea spiders. They are relatively small on the West Coast, but once again they become gigantic in Antarctica, growing to a foot wide or more. Woods says on many under-ice dives, he could spot 30 at once.

"They weren't skittering around," he says of the slow-moving creatures that use a proboscis to eat sea anemones and other immobile bottom dwellers. "You aren't going to get mobbed by sea spiders."

To study whether big sea spiders are more affected by oxygen constraints than smaller ones, Woods' team set up an experiment in the NSF's state-of-the-art lab aquariums at McMurdo Station. This involved an "aerobic workout" in which the spiders were turned on their backs. Most animals hate to be exposed on their backs, and the team measured how often the pycnogonids could right themselves in an hour. The exercise was done in normal McMurdo seawater and then water with reduced oxygen content.

Some big ones could only right themselves twice an hour, while a few smaller super-athletes could un-flip themselves 200 times.

"The idea was the big ones evolved because they were released from oxygen constraints," Woods says. "If so, low levels of oxygen imposed experimentally should impact the big ones more than the smaller ones. But we found they all suffered equally. That's how it goes. Maybe our workouts weren't realistic. Or maybe it's easier for spiders – with their extended, elongate bodies – to get oxygen to all of their tissues regardless of their size."

Woods also studies what would happen if Antarctic seas grow warmer from climate change. When environmental change strikes an area, many species often choose to migrate. But Antarctic sea creatures trying to stay cool would be stuck, he says, because they have a continent in the way to colder climes in the south. Water a few degrees warmer also could speed up metabolic rates.

"You could get a decoupling of life cycles from the seasonal pulses of light and algae that happen (each summer) down there," he says. "Many species might go extinct or be forced to evolve to survive."

After studying moderate ocean off Washington and cold Antarctic waters, the next phase of Woods' research could take him to some of the warmest seawater in the world – the Solomon Islands in the South Pacific.

"The water there is the heart of nudibranch diversity," he says. "What happens when you heat water up a lot? Do you see really small nudibranch egg masses? We plan to write a grant to take us there."

– By Cary Shimek

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