Fall 2013

The Planet, 2013, Fall

Mikey Jane Moran
Western Washington University

Huxley College of the Environment, Western Washington University

THE PLANET

THE MYSTERY ISSUE FALL 2013

DEAR READER,

When you were a child, did you ever flip over rocks? In the imprint of each stone, a myriad of many-legged creatures retreated from the light, worms wriggled deeper into the soil. Each rock held the mystery of what lay beneath, and once you turned one over, you had to know what was lurking under the next. Curiosity took over. Fingers got muddy.

This fall, The Planet started flipping.

This issue is about the process and pursuit of knowledge. We researched emerging theories about salmon navigation and trailed after scat-sniffing dogs, not for answers, but out of curiosity.

The more questions we asked, the more we plunged into the unknowns of science. How do octopuses camouflage seamlessly on the ocean floor if they cannot see color? Can North American bats outlast a deadly fungus? Despite our relentless research, we did not find concrete answers.

Instead, we found science is a progression of theories — a series of shifting paradigms. What we know today may be false tomorrow.

While uncertainty may be unsatisfying, as you read this issue, consider where we would be without the pursuit of mystery. Certainly not high in the forest canopy discovering new species of salamanders or deep in a cave, nose-to-infected-nose with a bat. Consider what might happen if no one investigated rapidly melting Arctic ice to discover an ecosystem on the brink of collapse or stopped to ponder what will happen to the people who live off this changing land.

The future is uncertain, but that does not mean we should stop asking.

Wonder away,

Mikey Jane Moran

Editor-in-Chief

The Planet Magazine
c/o Huxley College
Western Washington University
516 High Street, CF 220
Bellingham, WA 98225

Telephone (360) 650-3543
planet@wwu.edu

http://planet.wwu.edu

THE PLANET MAGAZINE is the quarterly student publication of Western Washington University's Huxley College of the Environment. We are dedicated to environmental advocacy through responsible journalism.

The Planet Magazine strives for accuracy and will correct any factual errors promptly and courteously. Please alert us if you spot any inaccuracies.

This issue of the Planet is printed on Mohawk Via uncoated bright white paper. It is made from 30% recycled content. Mohawk is a certified Women Owned Business Enterprise and is the first U.S. paper mill to offset 100% of its electricity with windpower renewable energy credits. It is also the first U. S. premium paper mill to shift toward carbon neutral production. Basically, they're environmental superheroes. We are proud to support them.

IN THIS ISSUE


02


14


25

ON THE COVER

Kraken the giant Pacific octopus plasters his tentacles to the glass of his tank in Bellingham's Marine Life Center.

- Kalena Walker

POPULATIONS

CAVING IN

STORY KRAMER JANDERS | **PHOTOS** KALENA WALKER

As the air grows chilly and food sources run out, many animals seek shelter to hibernate for the coming winter. Flying into caves and old mine shafts, bats expect a restful winter. Little do they know some of these hibernation sites are death traps.

IN 2006, IN A WELL-EXPLORED NEW YORK CAVE, a mysterious cave-dwelling fungus appeared on bats and claimed its first victim in North America. Researchers stood puzzled as bats began dying by the thousands. In early 2012, the U.S. Fish and Wildlife Service estimated nearly 6 million bats had died from the fungus, now classified as Pseudogymnoascus destructans. This fungal pathogen causes a disease called white-nose syndrome (WNS), in which white fuzz grows on the wings and muzzles of hibernating bats.

WNS has affected six different species of insectivorous bats in the eastern half of North America, and their populations have been decimated.

The fungus breaks down the skin tissue of the bats, creating sores on their wings, ears and muzzles and waking them during hibernation, said Katie Gillies, the imperiled species coordinator at Bat Conservation International.

The fungus was introduced by human transportation, but it now primarily spreads through bat-to-bat contact, Gillies said. Scientists believe the fungus kills the bats indirectly by causing dehydration and starvation.

According to White-nose Syndrome in Bats, a 2013 article in BMC Biology, the fungus has spread south from New York to Georgia, north into several Canadian provinces and as far west as Missouri.

According to Economic Importance of Bats in Agriculture, a 2011 article in Science, bats mainly feed in the night on forest and crop-dwelling insects. For example, one colony of about 150 big brown bats in Indiana has been estimated to consume 1.3 million pest insects each year. Big brown bats are one of the six known species to be affected by WNS.

Without bats in North America, agricultural losses are estimated from $3.7 billion to more than $50 billion. This estimate accounts for the reduced cost of pesticides for farmers because of the free service provided by bats. The impacts pesticides could have on soil and water downstream are not included in this estimate.

Researchers may not realize the true potential damage to agricultural centers until the disease spreads, said David Blehert, a microbiologist at the National Wildlife Health Center. Key agricultural centers at risk include Minnesota, Iowa and the central Midwest farm belt.

"We still have not seen WNS causing high levels of bat mortality in the most agriculturally rich regions of North America," Blehert said.

Bats in North America have evolved to coexist with many varieties of fungi in caves and mines across the continent. Scientists think humans accidentally introduced the fungus to North America from either Europe or Asia in the early 2000s, Blehert said.

According to White-nose Syndrome in Bats, WNS is present in European bat populations. However, they do not die from the disease like the bats in North America. Lab studies have documented North American little brown bats infected with WNS die after approximately two to three months of hibernation.

Bats look for hibernation sites, called hibernaculum, where the air temperature approaches freezing, said John McLaughlin, associate professor of environmental science at Western Washington University.

"The environments in which [bats] hibernate are cold, underground, dark caves and mines that are very conducive to fungal growth," Blehert said. "Think about your basement: You get mold growing on your walls because it is a dark and cool environment like these hibernation sites."

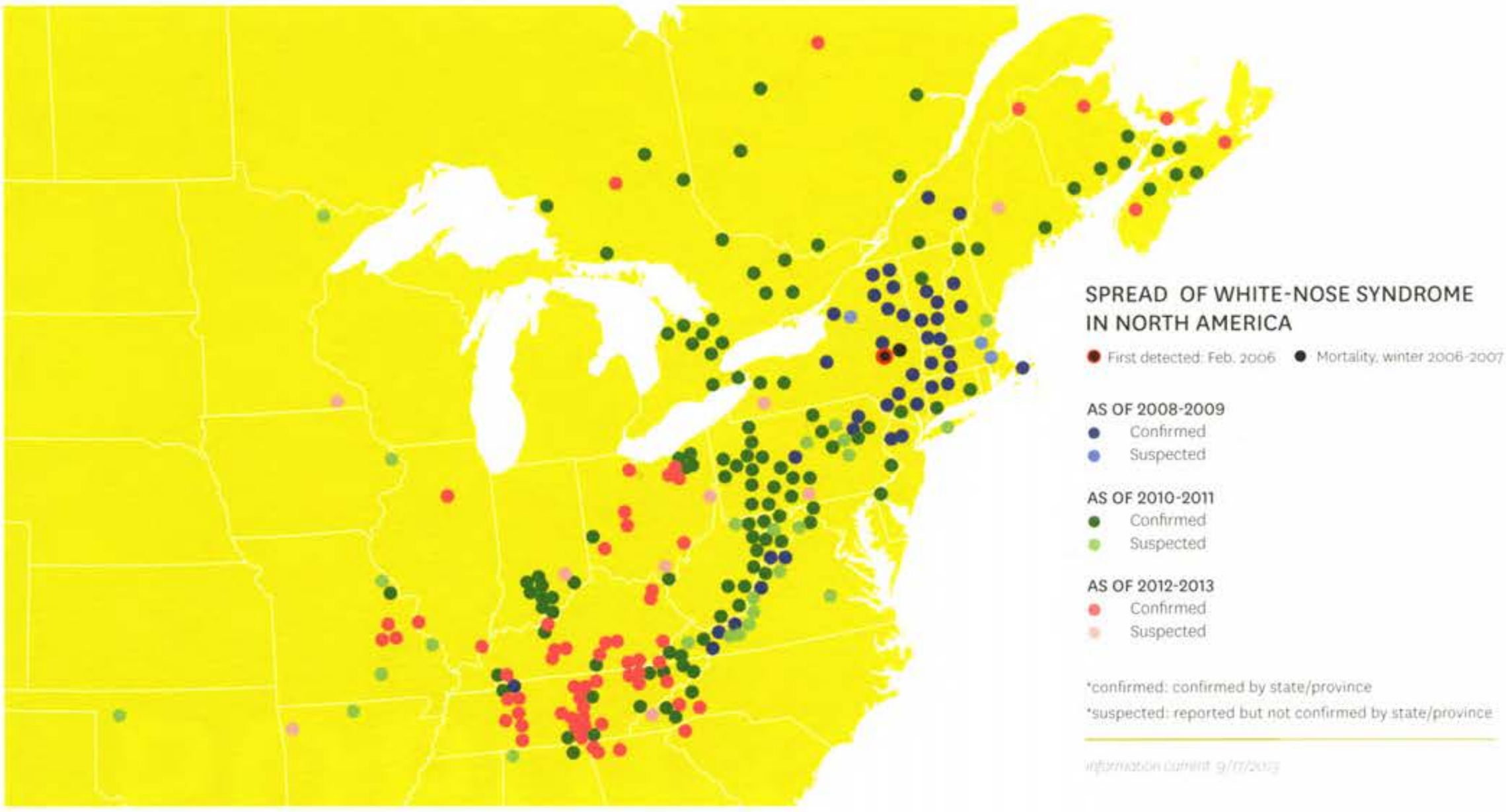
While hibernating, a bat goes into torpor, a deep sleep where the body is essentially shut off. The cold air temperature allows the bat to drop its body temperature, slowing its metabolism and preserving its fat reserves through winter, McLaughlin said.

The hibernating period is dependent on the region and the species of bat but can last from October to April, Gillies said.

Bats use their limited fat supply as an energy reserve to come out of torpor and move around naturally every couple of weeks, McLaughlin said.

OPPOSITE: *Oyster Dome is a popular Bellingham hiking destination, but it also looms over known bat caves where populations of big brown and little brown bats may reside. Even though these species are susceptible to white-nose syndrome, Washington bats seem to form smaller congregations, possibly decreasing their vulnerability.*

BELOW: *White-nose syndrome, a disease caused by a fungus, has affected the populations of six species of bats. The fungus grows on bats' skin, creates sores on their wings and muzzles and disturbs their hibernation, which wastes their energy reserves and potentially kills them. (Photo courtesy of Marvin Moriarty of U.S. Fish and Wildlife Service.)*



WNS disrupts the hibernation cycle of the bat by attacking and breaking down the skin on the wings and muzzle. This irritation likely causes them to wake up in a severely dehydrated state, Gillies said.

According to the 2012 article Bats and White-nose Syndrome, by M. Brock Fenton, many caves have been gated and closed due to the negative impacts of human disruption of hibernation cycles in bats. Bats infected with WNS will exhaust their energy supplies and water stores well before winter is over. Because bats feed mainly on insects, which are scarce during the middle of winter, they have no chance of replenishing their fat reserves.

"When the bats become affected they will fly out of their hibernation sites at any time of day, broad daylight, middle of January — swarms of bats exiting hibernation sites at a totally inappropriate time and then just dispersing and dying out on the landscape," Blehert said.

Bat researcher Greg Falxa of Cascadia Research, believes precautionary measures have slowed the human-caused spread of the fungus. Measures include signs and park rangers stationed outside of known large hibernaculum. However, bats are still transmitting the fungus to one another.

"Larger congregations of bats seem to be more vulnerable," Falxa said.

Falxa has been studying bats in the Northwest since 2001, but he believes not enough research is conducted on bats in our area. No one knows where the majority of Washington's bats go in the wintertime, Falxa said.

Two of the bat species affected by WNS, the little brown bat and the big brown bat, are found here in Washington.

Hopefully bats in Washington will be less vulnerable since they do not seem to form large congregations, Falxa said.

Eliminating the fungus here in North America is unlikely. Instead, Blehert's research is aimed at discovering a way to subtly manipulate the temperature and humidity conditions in bat hibernation sites to manage its growth.

Blehert is studying current environmental conditions to find out how the lethal disease is developing in North America versus Europe. In addition, he is studying whether bats in Europe have developed a resistance to the fungus.

His research may uncover a way for bats to coexist with this deadly fungus.

"Bats infected with WNS will exhaust their energy supplies and water stores well before winter is over."

KRAMER JANDERS is a senior pursuing a degree in visual journalism and business at Western Washington University. When he is not at school he enjoys photography, music and the outdoors.

KALENA WALKER is a junior pursuing majors in environmental science and photography. During her free time she drinks chai lattes and tickles octopuses.

THE FOREST ABOVE US

STORY JESS GIFFORD | **PHOTOS** BRENDAN WELLS

Thirty years ago, forest researchers left the ground on ropes and headed for the canopy. Since then, researchers have ascended trees taller than the Statue of Liberty to discover hundreds of species of mosses, count thousands of insects, locate nests of rare seabirds and even unearth two species of lungless salamanders.

ABOVE LEFT: *Jess Gifford, in a white helmet, examines the layer of humus high up in a big leaf maple tree. The humus layer in large trees is home to a variety of flora and fauna, including the licorice ferns growing out of the moss layer on this tree trunk.*

ABOVE RIGHT: *Mosses and lichens like the ones growing on this maple tree take nitrogen gas from the air and transform it into a usable form. When lichens die or are eaten, the nitrogen is passed on to other plants.*

PREVIOUS PAGE: *The view from more than 50 feet up in this cedar tree shows branches of the canopy reaching out for sunlight. These upper branches provide homes for birds, squirrels, insects, mosses, lichens and other life.*

THE TREE CANOPY IS A WORLD FULL OF DIVERSITY and complexity. Exposure to winds, temperature and moisture is constant. A layer of soil builds in the upper canopy, blanketing the limbs of the trees and providing a new habitat for huckleberry bushes and salamanders alike. Here in the trees, scientists have started researching Earth's hottest topic — climate change.

At neck-tipping heights, the trunks of old-growth trees in the Pacific coastal forests rocket up and out of the forest floor toward the atmosphere. These forests stretch from southern Alaska to northern California.

Because of the mild climate and plentiful rainfall, trees in a coastal environment, specifically conifers, can grow almost all year, attaining massive heights and girths, said Dave Werntz, forest ecologist and conservation director at Conservation Northwest.

The unique species in the Pacific Northwest — giant coastal redwoods, Douglas fir, Sitka spruce, Western hemlock and Western red cedar — make the coastal forests stand above the rest. The redwood trees found here are the tallest trees on Earth, measuring up to 379 feet. Though smaller than the redwoods, Douglas fir and Sitka spruce can still reach 262 to 295 feet in height, said David Shaw, forest health specialist and associate professor at Oregon State University.

Deformities, damage and disturbance constantly reshape tall trees, creating canopy architecture after one or two centuries. This architecture refers to the canopy's individual structure, how it is shaped and how branches are arranged, Werntz said.

"It is not until you get unique architecture that you get habitat that supports a huge number of lichens, bryophytes and ferns," Werntz said.

According to a 2004 study by Anthony Ambrose, leaves, twigs and bark trapped in crevices and on limbs decompose into humus, forming a major component of canopy soil. The humus layer is covered by epiphytes — plants growing on other plants — and creates a heavy, moist mat that covers branches and can retain large amounts of water.

Depending on the type of forest, epiphyte loads and time of year, the canopy can capture 5 to 15 percent of forest rainfall. Soil mats hold so much water they can moderate the humidity and temperature surrounding the tree, Shaw said in an email.

The moist, mossy layers blanketing the limbs of the canopy also provide a microhabitat for moisture-seeking species such as salamanders.

According to a 2007 study by Eric Forsman and James Swingle, researchers confirmed two species of lungless salamanders are partial canopy dwellers. Lungless salamanders breathe through their skin and depend on moist habitats like those found in the canopy.

Researchers find the highest concentration of canopy-dwelling salamanders in Douglas fir habitats. Because they grow quickly, Douglas fir trees are a source of lumber in the Pacific Northwest, said Maureen Ryan, conservation researcher at the University of Washington.

"At neck-tipping heights, the trunks of old-growth trees in the Pacific coastal forests rocket up and out of the forest floor toward the atmosphere."

Amphibian populations are declining worldwide, and in temperate regions, their disappearance is due in part to habitat loss.

"In forestry, some species will be able to bounce back pretty quickly after a clear cut; other species will not, based on what they are sensitive to, [such as] temperature changes and moisture changes," Ryan said.

Amphibian populations are also declining due to climate change, and Ryan has observed this in her research. As the climate is warming, the resources salamanders depend on are diminishing.

"We are living in that same space. We are walking around in these forests where they are below our feet, and everything that is happening in that space is happening to us," Ryan said.

Rotting logs, leaves, bark and branches that fall on the forest floor are an important part of the habitat for salamanders and the forest ecosystems they create are an important component of climate change. The rich soil of a costal environment nurtures massive trees, which collect carbon from the atmosphere. These trees decay slowly, storing the carbon long after their death, Werntz said.

"The climate angle — that makes these forests globally unique in terms of the amount of carbon they hold and store," Werntz said. "There are many of us who believe any climate mitigation policy is going to need to look at the forests in the Northwest as a way to keep as much carbon in storage as possible to help offset the ravages of climate change."

While decaying matter in old-growth forests typically releases carbon, scientists at the Wind River Canopy Crane Research Facility in Gifford-Pinchot National Forest in southwest Washington discovered this particular 450-year-old forest is a carbon sink. Trees in the Gifford-Pinchot forest grow quickly and decay slowly because of high rainfall. When the amount of carbon that plants take in exceeds the amount decaying matter releases, the forest is considered a sink. However, in drought years, the forest can become a source of carbon, said Shaw, who was part of the canopy research team from 1994 to 2005.

The canopy crane was a 278-foot construction crane rigged with a gondola bucket, or man-basket, on an arm that reached across nearly five acres. It opened up an area for discovery in a place that had been inaccessible for scientists, Shaw said.

Although the canopy crane was disassembled, research at the Wind River site continues, as does the quest to understand how old-growth forest canopies will weather climate change.

The future remains uncertain for the forest canopy, the salamanders depending on it and the humans who benefit from the multitude of its resources.

"We are reliant on the same basic resources to live as they are," Ryan said. "We share the same fate."

JESS GIFFORD is a Fairhaven student with a self-designed concentration in environmental stewardship. She enjoys reveling in nature's mysteries and sharing them with others.

BRENDAN WELLS is a junior studying environmental stewardship and activism at Fairhaven College. He is an avid whitewater kayaker who spends his free time documenting kayaking adventures and environmental issues through film and photography.

ABOVE: *Moisture-seeking salamanders, such as this western redback, thrive on the forest floor, while others, such as the clouded salamander venture into the high canopy. Humus layers and mosses can retain large amounts of water, helping regulate moisture in the canopy and on the ground during heavy rain and drought.*

LEFT: *Downed and decaying wood provides habitat for species such as salamanders. Old-growth trees in the northwest decay slowly and can store carbon for many years after their death.*

SHIFTING SKIN

STORY BRITTANY DURAND | **PHOTOS** KALENA WALKER

Suctioned to the corner of a glass tank, the Bellingham Marine Life Center's giant Pacific octopus rests peacefully, its body a pearl-white color. Children wander in and form a circle around the tank, their chatter startling the octopus awake. In a matter of seconds, its color changes from off-white to bright red. It releases its tentacles from the glass and wades into a hole underneath a log and disappears into its surroundings.

OCTOPUSES AND SOME OTHER CEPHALOPODS have the fascinating ability to change colors, patterns and textures despite being colorblind. Given their complex anatomy, scientists are baffled about how the octopuses use camouflage as a hunting and defense mechanism without color vision.

Octopuses have some of the most developed, complex brains of invertebrates, said Deborah Donovan, a biology professor at Western Washington University.

Their unique eyes contain only one pigment, said Roger Hanlon, senior scientist and professor at Brown University. In order to see color there must be a minimum of two pigments. Unlike octopuses, humans have three pigments and predatory species, like birds, can have up to four. Even though octopuses have a green-blue pigment they are most likely seeing black and white, Hanlon said.

Octopuses have cells called chromatophores, which are bags of different colored pigments. Muscular fibers surround the chromatophore cells and can contract, squeezing the colored cells to the surface to show a particular pigmentation, Donovan said.

According to Katherine Harmon's article Skin Deep, published in 2013, the chromatophores contain five different colors: black, yellow, orange, red and brown. Along with the chromatophores, the skin contains leucophores, which are white elements that reflect light to enhance octopus camouflage.

When Hanlon and his team searched DNA in the skin of cuttlefish, a relative of the octopus, they found light-sensing genes. This led to the hypothesis that light sensing could be happening in the skin.

Octopuses have two methods of color matching — active and passive. Scientists do not know how octopuses actively change color, but passive color matching has to do with light reflection, he said.

"They are white in white light, blue in blue light, red in red light and green in green light," Hanlon said. "The bottom layers of their skin are reflecting the ambient wavelengths faithfully, which is a form of passive color matching."

However, leucophores cannot effectively reflect other essential skin pigments such as browns and yellows, indicating the chromatophores that produce these colors may be actively regulated, Hanlon said.

"We are batting zero trying to get some unequivocal, good experimental data," Hanlon said. "The other option is we are chasing a red herring and this is all nonsense."

According to a 2012 study in the Proceedings of the National Academy of Sciences (PNAS), researchers discovered specialized cells called iridocytes within the skin

"We are batting zero trying to get some unequivocal, good experimental data."
-Roger Hanlon

LEFT: *These photos, taken seconds apart, illustrate the rapid color-changing abilities of an octopus. The top was taken when he was napping between shots; the bottom shows his eye turning red in response to hearing the camera shutter.*

of squid. To better understand octopus camouflage, this study looked at squid cells. Like leucophore cells, iridocytes can develop folds in the cell membrane, which help reflect light.

According to a University of California, Santa Barbara press release updating the 2012 PNAS study, octopuses create a variety of patterns when it comes to predators, mating and hunting. They can make their skin bright red, which could signal anger, or zebra striped, which could be an invitation for mating.

Hanlon has witnessed the color changes of these creatures first hand.

"It is the most dynamic and wonderful process," Hanlon said.

Cuttlefish are also able to control the texture of their skin by merely looking at a surface, Hanlon said. The eye looks at the background and is able to determine its three-dimensional texture then replicate it in their skin.

"Not only can they change their color, but they can change the texture of their skin," Donovan said. "You do not even know they are there."

Cuttlefish are still able to determine the exact background texture through a piece of glass or even with a simple two-dimensional photograph. They could only be using their vision to do this, Hanlon said.

"It is very perplexing and seemingly incomprehensible to humans," Hanlon said.

According to a 2012 study by Noam Josef, background factors like light intensity, contrast, angles and the size of surrounding objects provide the visual cues that help a cephalopod camouflage.

According to the PNAS article written in 2012, females have the ability to essentially mimic a male's appearance to defend against undesired mates. They can change their skin to look just like another octopus.

Octopuses learn very quickly from one another. They see what another octopus is doing and within seconds can mimic the action, Donovan said.

Scientists are constantly developing new theories and hypotheses about octopus camouflage.

After two and a half years of working with a group of postdoctoral scholars, graduate students and experts on the subject, Hanlon is still stumped when it comes to these creatures. They do not have any firm answers yet, but research is in progress.

"If you do not try the hard stuff you will never figure out the cool stuff," Hanlon said.

BRITTANY DURAND is a student at Western Washington University pursuing a degree in public relations. Her favorite place to be is with her family back home, surrounded by acres of hop fields and farmland.

KALENA WALKER is a junior pursuing majors in environmental science and photography. During her free time she drinks chai lattes and tickles octopuses.

TOP LEFT: *Joseph Warn of Seattle peers at Zero, a giant Pacific octopus, as it grabs food from a feeding pole held by Seattle Aquarium staff. Due to scheduled feedings, octopuses do not need to change color as they would in the wild while hunting.*

MIDDLE LEFT: *Cephalopods, such as this giant Pacific octopus, have color-changing abilities used for hunting, defense, attracting mates and expressing mood despite being colorblind.*

BOTTOM LEFT: *Cuttlefish, cephalopods with w-shaped pupils, have similar light-sensing and color-changing abilities. Cuttlefish can determine 3-D backgrounds and replicate textures, even through a pane of glass.*

SNIFFING FOR **SCAT**

STORY ISAAC MARTIN | **PHOTOS** CONNOR GRIESEMER

Tucker, a Labrador retriever mix, and his trainer Liz Seely search the waters of Puget Sound from May through October. Tucker leads the boat with his body language as they navigate the San Juan Islands. Perched on the bow, he sniffs for whale scat.

TUCKER IS ONE OF 16 DOGS WORKING FOR CONservation Canines, a fleet of tracker dogs who search for endangered and rare species of animals. These dogs provide assistance to study and conserve the lives of species such as killer whales, grizzly bears, elephants and caribou.

Conservation Canines uses a unique searching technique. Rather than searching for the animal itself, the dogs sniff out the animal's scat — the scientific word for poop.

Most dogs' noses are one thousand times more sensitive than a human's. According to a 2013 study in Journal of Breath Research, dogs have more than 220 million olfactory receptors in their nose. Humans have just 5 million.

The dogs can find a piece of scat smaller than a grain of rice, said Heath Smith, the program coordinator of Conservation Canines.

Seely and Tucker's work contributes to the study of declining resident killer whale pod populations in Puget Sound. The killer whale population faces three main threats: the decline of the Chinook salmon they feed on, toxicants found in the waters and disturbance from private and commercial whale-watching vessels, Seely said.

By analyzing a sample of scat, the research group can determine the whale's diet, reproductive health and toxicants that may be in the whale's system, Seely said.

Searching for scat is almost completely non-invasive toward the endangered animals. Keeping a distance reduces stress on the animals and also protects fragile habitats.

In 2012, Conservation Canines searched for a rare species of salamander in New Mexico. Researchers used to find salamanders by tearing into a log and seeing if any scurried away. This destroyed habitats and further endangered the amphibians. Now the dogs can find where the salamanders are hiding and there is no need to tamper with their home, Smith said.

Tucker can pick up the scent of whale scat from a mile and a half away. When they find the scat, the crew makes sure to keep its distance from nearby killer whales.

"Most of the time we are 400 to 600 meters from the whale," Seely said. Maintaining a proper distance prevents the whales from becoming stressed.

According to the Washington Department of Fish and Wildlife, the state requires all vessels to stay 200 meters away from killer whales.

"We are considered non-invasive. We are sampling outside of the federal and state guidelines," Seely said.

The method of using a dog to find whale scat relies on communication between Tucker, Seely and the boat driver. The boat starts perpendicular to the wind, turning against it when Tucker picks up on the scent. He then leans over the bow and motions toward the direction of the scent while Seely watches him and uses hand signals to tell the driver which direction to go.

"We have it down to an art form," Seely said.

Whale scat looks similar to splattered pancake batter on a hot grill. The ideal sam-

PREVIOUS PAGE: *Tucker searches for the scent of whale scat, or poop, while his trainer Liz Seely directs the driver of the boat. They hunt for scat, six months out of the year in the waters of the Puget Sound. (Photograph courtesy of Jane Cogan.)*

BELOW LEFT: *Chester is rewarded with a game of fetch after finding a scat sample.*

BELOW: *Heath Smith, program director for Conservation Canines, stands at the training facility for service dogs. Heath leads a team of researchers who search for killer whale scat using a boat and a highly trained dog that can find a grain-sized piece of scat.*

ple size is about as large as a silver dollar, but it ranges from the size of a lentil to a dinner plate, Seely said.

Tucker sniffs out the floating scat for eights hours a day, and when he finds a sample, he is rewarded with a game of tug-of-war.

Although Seely is successful at tracking poop, she does not know why the whale population is in decline. After this season, the population of resident killer whales dropped from 83 whales to 80, and no surviving calves were born, Seely said.

The biggest goal for Conservation Canines this year is to find out why the females are not reproducing, or if they are, why no calves survived. Conservation Canines hopes they can solve this problem through hormone and toxicant analysis.

After scat is collected on the boat, the sample is sent to Jessica Lundin who analyzes the sample and tests the level of toxicants, such as the flame-retardant PCB, that can be stored in whale fat. Whales are exposed to toxicants through their diet and environment.

Lundin is a graduate student working on her dissertation for environmental toxicology at the University of Washington. Her research evaluates the presence and impacts of environmental toxicants.

If Lundin notices high levels of toxicants in the whale scat, she can use it as a starting point for remediating toxicant levels in the water.

"We are looking at associations of toxicant level and successful pregnancy," Lundin said.

More than 100 scat samples are gathered and examined in the lab every year. Lundin is compiling data from these samples to better understand the driving force in the decreasing population of killer whales.

"We will stay on the water as long as we can and continue to gather these samples and gather this data," Lundin said.

As the number of resident killer whales decreases, Conservation Canines provides an effective method to gather data without further endangering the pod. Tucker's work fuels research that may someday lead to a stable whale population in Puget Sound.

ISAAC MARTIN is senior studying studio art and visual journalism at Western Washington University. He enjoys snowboarding, skateboarding, pizza and punk rock.

CONNOR GRIESEMER is a visual journalism major and internet resource creation and management minor. Other than photographing for The Planet, he enjoys surfing, skiing and enjoying life in the great outdoors.

"Dogs have more than 220 million olfactory receptors in their nose. Humans have just 5 million."

BELOW: *Smith examines his freezer full of various endangered species' scat samples. His method of noninvasive research is ideal because no human contact is involved, which prevents stress for the animals being tracked.*

BELOW BOTTOM: *Trainers test the dogs starting at the animal shelter. Smith put Chester through considerable training before tracking scat in the field.*

ON THE EDGE
OF CLIMATE CHANGE

STORY & PHOTOS JAMES LEDER

ACCORDING TO A 2013 STUDY PUBLISHED IN Geophysical Research Letters, summer air temperatures in the Arctic are the highest they have been in 44,000 years. While the Arctic warms at three times the global average rate, indigenous communities inhabiting these remote areas, who have made little contribution to climate change historically, are shouldering the burden of the climate crisis long before those at fault. With changing temperatures throwing ecosystems into chaos, the land that northern Alaskan natives rely upon for their livelihoods is becoming unpredictable.

That is why I am here, wading through bug-ridden swamps, questioning my own sanity for embarking on a 200-mile wilderness trek alone. In the next 12 days, I plan to traverse the Brooks Range from south to north, walking from Arctic Village up the East Fork Chandalar River valley, over Guilbeau Pass and floating the Hulahula River on my packraft out to the Arctic Ocean.

GWICH'IN HOSPITALITY

While crashing through a stand of alders on the banks of the Junjik River, roughly 10 miles north of Arctic Village, I hear the unmistakable hum of an outboard motor. I wave as the vessel approaches and a family of three beaches their boat at my feet, taken aback by my presence on the remote river. They welcome me aboard and a few river bends later, we arrive at their camp.

For the Gilbert family and friends — eight Gwich'in in total — the place is a favorite summer campsite, complete with freshly caught whitefish sizzling over the fire. Gwich'in is an Alaskan Native language group of about 1100 people that primarily inhabits a vast swath of land in Alaska's northeast corner.

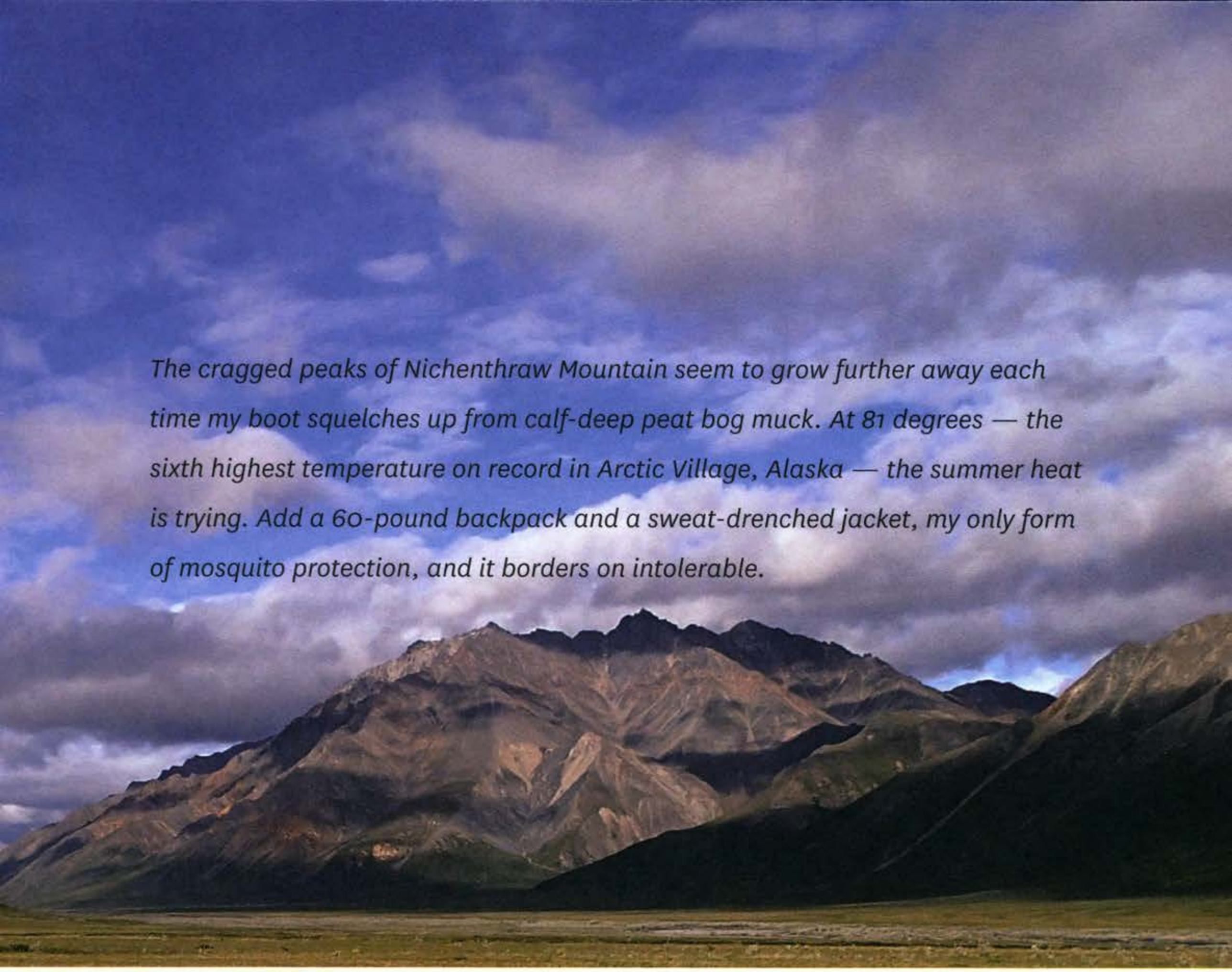
Jack Wilbert, a close friend of the Gilberts, is trimming a caribou shoulder blade when I arrive. He passes me a chunk of dried flesh and I chew it enthusiastically, savoring the rich flavor and fantasizing about trading my rations of corn grits for more of the wild game.

I learn the Gilbert family harvests about six caribou every year, which is fairly typical of a Gwich'in family in Arctic Village. Supplemented with whitefish, salmon, grayling, moose and a variety of fowl, they rarely require any store-bought meat products. While we discuss traditional subsistence practices, the Rev. Trimble Gilbert, traditional chief of Arctic Village, stirs a pot of caribou stew cooking on the fire.

"We can not live without caribou," Gilbert says.

This protein source is indispensable to the Gwich'in, often referred to as "people of the caribou," because they cannot drive to the local grocer and buy beef. No roads connect Arctic Village to the outside world. High costs of air transport mean the fresh nutritious foods I often take for granted are seldom an option for residents of this remote settlement.

In the morning I munch on caribou stew leftovers while Gilbert pencils in the best route to Guilbeau Pass on my map. After breakfast we motor up the Junjik a mile or so to one of



The cragged peaks of Nichenthraw Mountain seem to grow further away each time my boot squelches up from calf-deep peat bog muck. At 81 degrees — the sixth highest temperature on record in Arctic Village, Alaska — the summer heat is trying. Add a 60-pound backpack and a sweat-drenched jacket, my only form of mosquito protection, and it borders on intolerable.

the tribe's main hunting lookout spots. While sitting atop the knoll, Gilbert makes a prayer asking for peace and harmony within his people, as well as my safe arrival in Kaktovik. I gaze out over the traditional hunting grounds of the Gwich'in tribe as he speaks — entranced by the beauty of the landscape and the graciousness of its people.

In reality, the consumer culture of affluent populations is pushing these once-pristine northern ecosystems into a state of flux.

"Nowadays our world is not the same," Gilbert says.

In a sweeping motion of his arm, he indicates a patch of dense evergreen forest that he recalls was once open tundra grass. As the climate warms, peat bogs and lakes dry up, making the land more hospitable for woody brush and trees. The change in foliage makes life harder for the caribou, and the decline in health of the herd is evident to the villagers, Gilbert says.

The darkly colored spruce trees contrast the snow during winter months, and the decrease in the landscapes albedo, the measure of a surface's ability to reflect sunlight, further contributing to warming trends.

Changing weather patterns mean elders are no longer able to comfortably predict the weather.

According to a 2010 study conducted by Betsy Weatherhead in the high Arctic of Nunavat, Canada, changes in the persistence of weather — the tendency of a weather condition to repeat itself — have been significant over the last 15 years, especially during spring. As persistence declines, daily variation in weather will be more dramatic.

Henry Huntington, the Arctic science director for the Pew Charitable Trusts, has studied indigenous peoples' interactions with their environment in the Arctic for more than 20 years.

"You can always think up excuses for why people's prediction skills have gotten worse. You used to live out on the land and pay attention and now you sit inside and watch TV and glance out your window. No wonder you are not in touch with things as much. No wonder you are not any good at it," Huntington said. "Betsy was able to show there is a demonstrable, quantitative reason why people might be having a harder time predicting the weather."

When rescue personnel are hundreds of miles away, not being able to predict weather can have serious implications.

"People have been caught in storms because they were unexpected, whereas in the past, they would have seen what was coming," said Nancy Lord, Alaskan non-fiction writer, whose latest book illustrates the impacts of climate change on Alaskan natives.

RIVER BRAIDS AND CARIBOU TRAILS

After three days of stumbling through fields of tussocks, top-heavy clumps of grass surrounded by deep moats of water, I reach the braided section of the East Fork at last. I cringe as I peel off my perpetually saturated socks, but I cannot help feeling a little pride at the collection of blisters I have amassed. With tussock-tempered resolve, I embark on the river braids the following morning, pausing on occasion to dip my palms in a brook for a drink or to admire the mosaic of wildflowers carpeting the valley. My blistered soles rejoice in frigid glacial water as I beeline for Guilbeau pass, fording the Chandalar countless times in the process.

Camping below Guilbeau Pass is like toeing the line before a marathon. I shamelessly lick the last of my butter off an inside-out Ziploc bag to fortify my energy stores, amused at my enthusiasm for the unconventional snack.

The valley bottlenecks as I approach the pass, and deep-seated migration trails from the Porcupine caribou herd become starkly defined. For tens of thousands of years, caribou have trod this route, once sharing the forage with mastodons and evading sabre-toothed cats on their migration to the rich foods of the coastal plain. I silently thank them for the millennia of inadvertent trail maintenance as I cross the pass in high spirits.

Reveling in the luxury of downhill travel, I make for the swift waters of the Hulahula. After covering nearly 100 miles of wilderness on foot, it is especially enjoyable to float down the high alpine river in my raft, with nameless peaks gliding by. I travel the whitewater in my 5-foot inflatable raft, with frequent stops to thaw my extremities over hastily constructed driftwood fires. After three days, I arrive at the place where the caribou I dined on 10 days earlier with my Gwich'in friends was likely born.

The flatness of the coastal plain is mind-numbing. Over and over I mistake seagulls resting on distant sand bars for polar bears, cursing my lack of depth perception as I watch another bear take flight to reveal its true identity.

As I pull my raft onto Arey Island, a 7-mile-long barrier island on the edge of the Arctic Ocean, the first thing I see is polar bear tracks. I have no choice but to follow the impressions east toward Kaktovik, trying to keep my mind off the prospect of encountering one of the formidable creatures. Looking north, I see amber rays from an ever-present sun peeking through the clouds, which reflect their light off the glassy water. I fall asleep on the beach to a crackling fire and contenting thoughts of finding Kaktovik, an isolated Iñupiat settlement of about 250 Alaskan natives on Barter Island— now a mere 10 miles away.

ON THIN ICE

Intentions of reaching Kaktovik are suspended as I am woken by the sound of rain spattering my tent in high winds, equivalent to the sound a machine gun. A few miles of sodden trudging brings me to an impasse. I sit anxiously in my raft on the eastern edge of Arey Island, squinting at dense coastal fog in a futile effort to locate Barter Island, my link to civilization. I have two options: either take out my compass and paddle out into icy white caps, risking going adrift in remote arctic waters, or hunker down and hope the fog lifts before my fresh water runs out.

My decision to wait out the weather is rewarded by boat noises. Three smiling Kaktovik locals beach their boat on the island, and I find myself in a warm house shortly thereafter, sipping tea and eating caribou stew with new friends. Bruce Inglangasak generously entertains me in his home for a couple of days while I await my flight out of Kaktovik, talking extensively with me about the past and present state of his homeland.

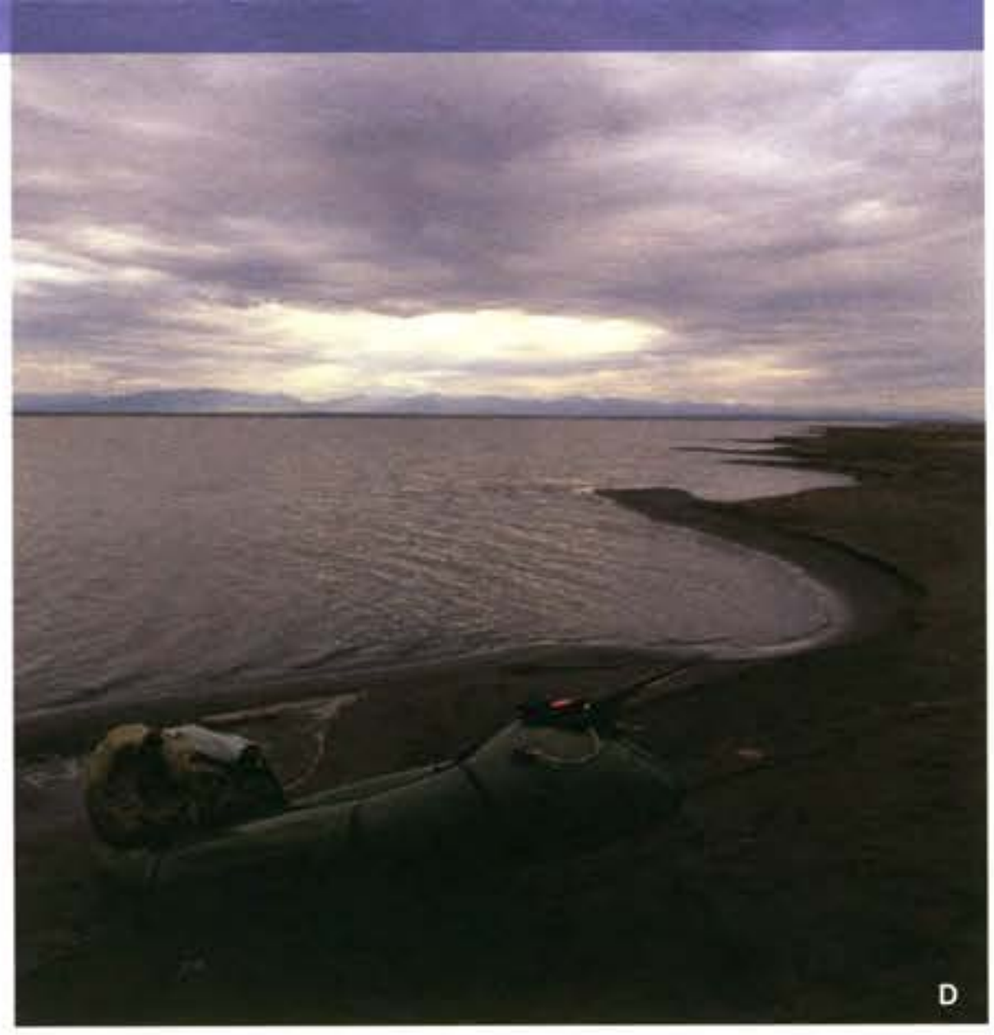
Inglangasak, a 57-year-old Iñupiaq, operates a polar bear-viewing business out of his home in Kaktovik. In recent years, he has witnessed an explosion of polar bears visiting Barter Island in the fall. It does not take a scientist to understand this strange behavior is a direct result of the changing climate. As the Arctic warms, vast expanses of sea ice are converted into water.

"The temperatures we are getting here in the summertime are just crazy," Inglangasak says with raised eyebrows.

I stroll out along the airstrip to the village bone pile — a heap of whalebones and scraps from bowhead whale harvests with an iceless ocean for a backdrop. Forty years ago I would

PREVIOUS PAGE: *Heat in Arctic Village, Alaska reached 81 degrees Fahrenheit this summer, the sixth highest temperature ever recorded in Arctic Village. As the Arctic warms three times faster than the global average rate of change, indigenous communities inhabiting these remote areas are shouldering the burden of the climate crisis.*


C


D

A: *Trimble, Gregory and Jewel Gilbert and family friend Jack Wilbert stand above their traditional hunting grounds in the East Fork Chandalar River valley.*

B: *Looking north from Arey Island, one can see an ice-free horizon. Summer sea ice has declined in volume and extent by roughly 50 percent, or about 1.5 million square miles since 1950.*

C: *An Iñupiat fishing camp sets up to harvest Arctic char while they feed close to shore. Bruce Inglangasak and Jack Kayotuk found me in the shelter on the right, unable to cross over to Barter Island due to dangerous weather conditions.*

D: *Cold temperatures cause ground water to freeze and accumulate layers of ice called aufeis — pictured here on the East Fork Chandalar River.*

have been looking out at a myriad of icebergs and a wall of multi-year sea ice that does not melt in the summer but accumulates layers, providing a habitat for arctic animals.

Polar bears frequent the coast more and more as the ice retreats up to hundreds of miles from shore. The bears are estranged from the ice until colder winter temperatures bring it within swimming distance. The bone pile becomes an increasingly vital food source as more bears become land-bound.

Polar oceanographer Peter Wadhams took part in the first circumnavigation of the Americas in 1970 and has been studying sea ice ever since.

"In those days the ice was almost right up against the coast of Alaska right through the summer," Wadhams said.

Arctic scientists are fervently collecting data to determine the causes of this massive disappearing act.

Snow-covered ice reflects about 80 to 90 percent of solar radiation, mitigating any heating effect. Open water has an albedo of about 10 percent — meaning 90 percent of radiation is absorbed, Wadhams said.

"If you replace sea ice with open water, you are absorbing far more solar radiation than you used to absorb because it was covered with ice," Wadhams said.

Just as the upsurge of spruce trees around Arctic Village contributes to warming trends by decreasing albedo, highly reflective sea ice melts, exposing murky waters and setting a similar warming trend in motion.

"In the summer now, you have about 1.5 million square miles of ice remaining when you used to have about 3 million," Wadhams said.

THE TREK

James' 200-mile journey, by foot and boat, from Arctic Village to Kaktovik:

A. Arctic Village
B. Guilbeau Pass
C. Arey Island
D. Kaktovik, Barter Island

Inglangasak tells me how the effects of climate change are seen in the declining quality of the caribou population around Kaktovik. Like the Gwich'in, the Iñupiat also obtain a large portion of their livelihoods from hunting caribou.

"The caribou are really poor this year — too many bugs. They spend all their time running from bot flies and mosquitos instead of eating," Inglangasak says.

He demonstrates the amount of fat on recent caribou kills by holding his thumb and index finger about a quarter of an inch apart — a fraction of what Iñupiat tribes have traditionally harvested.

According to a 2009 study published in the Global Change Biology Journal, abnormally large bug populations are linked to warming air temperature trends.

However, these problems stand in periphery to the looming ramifications of further sea ice melt. For indigenous people, sea ice is a means to an end.

"What they are really curious about is not just sea ice for its own sake, but sea ice as a way to get out to what you want to catch and eat," Huntington said.

As sea ice integrity degrades, ice-related species become scarcer and traditional native hunting practices on ice become dangerous. Elders can no longer fully rely on the base of knowledge they have inherited from their ancestors.

"People used to look to elders for their experience and their advice, and now the elders do not really know. They cannot predict in the same way they used to be able to. The whole stability is gone," Lord said.

On my walk out to the bone pile I pass a crude wall of corroding barrels lining the northern edge of the runway, placed there by the air force in an effort to reinforce the sea bank and prevent Kaktovik's only runway from being washed away. As zones of open water expand, storm intensity heightens and subsequent beach erosion might force Kaktovik's residents to relocate their village further inland.

More open water boosts storm intensity because ice naturally breaks up and diminishes the power of waves. When sea ice is removed storms have more space to generate waves, and an increased rate of coastal erosion is the inevitable result, Wadhams said.

For a community like Kaktovik that has a strong cultural attachment to a specific geographical place, relocation is impossible to imagine. It is as if a family had occupied the same sturdy home for too many generations to count and some abstract process was eroding the very brick their house was built with.

On my final morning in Kaktovik, I stare out Inglangasak's living room window at a polar bear sow gnawing on a year-old whalebone, representing the political and ecological turmoil unfolding around her. I cannot help wonder about the fate of the species — a fate reflected in the futures of indigenous communities that share the ice bear's struggles through their deep connection with the land.

"Their traditions are evolving all the time. Their way of life is evolving, so I would think the cultures will survive, but they will be different," Lord said.

The plight of Alaskan natives in the face of climate change will only get more intense in years to come. Though they are among the few living at the epicenter of one of Earth's most rapid ecological transformations, they — like so many around the world — have limited power to address the problems imperiling their culture.

JAMES LEDER is a junior pursuing an environmental studies degree at Western Washington University. Hailing from Fairbanks, Alaska, he enjoys blueberry picking, chasing Dall sheep and extended wilderness adventures.

"As sea ice integrity degrades, ice-related species become scarcer and traditional native hunting practices on ice become dangerous."

LEFT: *Bruce Inglangasak peers into a traditional ice cellar, called* Sigl-uaqs *in Iñupiaq, the native language of Iñupiat people. Underground meat storage is becoming more unreliable due to melting permafrost. When the permafrost that constitutes the walls of the cellar melts, it leeches water into stored food, causing mold and making the food unfit for consumption.*

NATURE'S CLOCK

STORY NONTAWAT THAMMAWAN | **PHOTOS** BRENDAN WELLS

Humans live by the clock. We flood our waking hours with appointments, hobbies, friends, work, school and projects until our schedules overflow and spill into time we should spend sleeping. We try to ignore the clock on the wall, but we cannot ignore the clock within us.

IN 1729, FRENCH SCIENTIST JEAN-JACQUES d'Ortous de Mairan noticed plants in his garden were opening and closing their leaves at the same time everyday and wondered how they kept time. Sunlight was an obvious hypothesis, but it did not satisfy de Mairan's curiosity. When he moved the plants to a dark room for observation, they stayed on schedule, which meant some internal mechanism was keeping of track of time. After many studies, scientists found most organisms possess an internal time-keeping device called a circadian clock.

"Circadian clocks drive circadian rhythms, which are the physical, mental and behavioral changes in organisms within a 24-hour cycle."

Circadian clocks drive circadian rhythms, which are the physical, mental and behavioral changes in organisms within a 24-hour cycle. Nearly all life on Earth, from single-celled bacteria to fruit flies to humans, have internal clocks. Birds use these clocks to time migration, plants for photosynthesis and humans for sleep patterns.

According to a 2008 article written by Lane Brown and Phyllis Robinson in the Chronobiology International Journal, organisms have a master circadian clock located in the brain that controls the rhythms of the body's activities.

Circadian clocks work like a hand-wound watch. They can be fast or slow, and they need resetting every day. A human's circadian clock can only overcome jetlag when it synchronizes with light in a new time zone.

Since humans are too complex to study, Susan Golden, co-director of the Center for Chronobiology at the University of California, San Diego, studied the clocks using a simpler specimen — single-celled photosynthetic microorganisms called cyanobacteria.

According to a 2008 article in the Journal of Bacteriology, researchers found a gene for circadian input in cyanobacteria called kinase A (CikA). The gene is responsible for the circadian clock synchronization with light. If the CikA gene is mutated, the cell is not able to reset its clock in response to changes in light. It becomes permanently jet-lagged.

"When we talk about organisms having circadian rhythms, we really mean that they have an internal timing device," Golden said. "[This] timing system is not being driven by the environment. It is internal, genetic and it can be inherited."

Entire families can be genetically predisposed to inheriting the same sleep disorders, which can cause them to fall asleep four to eight hours earlier than average, Golden said.

Because circadian rhythms can function independently of environmental stimuli, people should remain on a similar sleep schedule even if they are kept in the dark all week, Golden said.

According to an article on the University of Utah website written by Lee Siegel in 1971, scientists identified the first clock gene, called a period gene. It functions as a central timekeeper, while another gene, the timeless gene, synchronizes with light to reset the clock. Both genes are expressed in the photoreceptor cells of the eyes.

The genes work together to create the basic mechanism of the clock in fruit flies, said Amita Sehgal, John Herr Musser professor of neuroscience and Howard Hughes Medical Institute investigator. The master circadian clock regulates the other clocks through these genes, which influence bodily functions, such as the cardiac and metabolic systems.

"We still do not know exactly how the clock makes the 24-hour period or exactly how it works," Sehgal said. "That is still a big black spot."

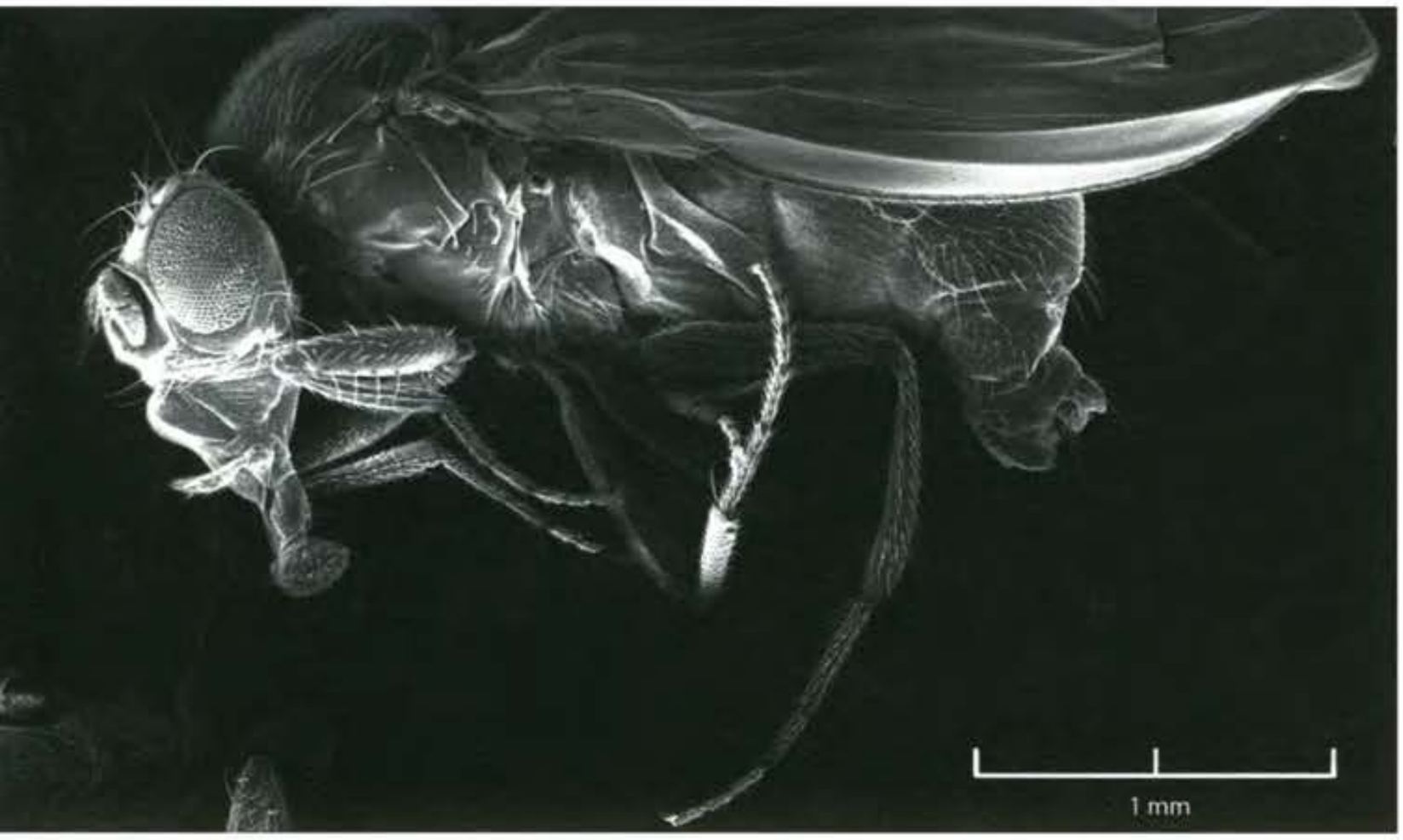
Studies on fruit flies allow scientists to identify similar clock genes in mammals. Examining the sleep cycles of fruit flies helps scientists understand the role of circadian rhythms in humans.

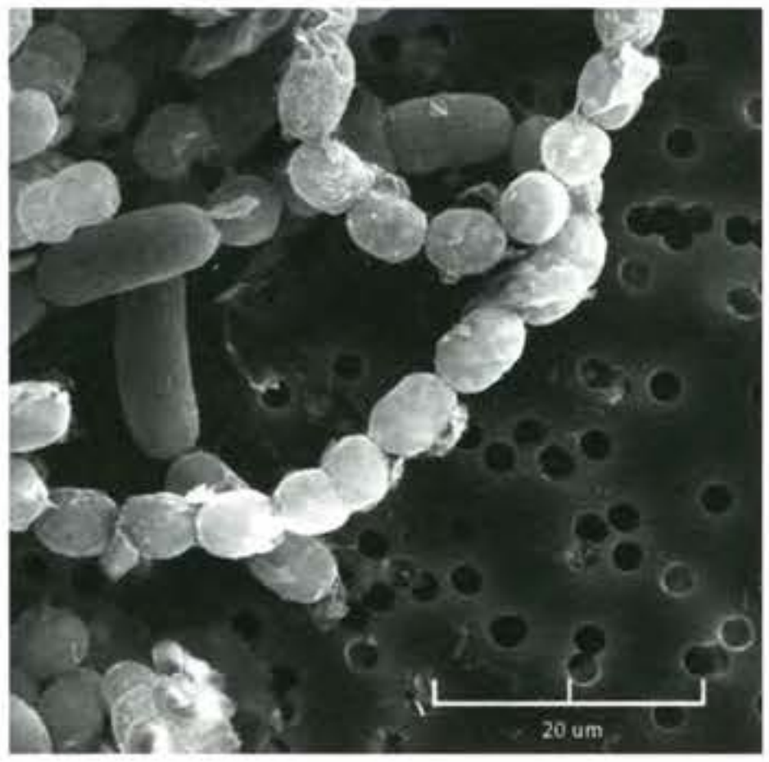
Researchers discovered that fruit flies sleep like humans, said William Joiner, assistant professor of pharmacology at the University of California, San Diego. Fruit flies are less responsive to external stimuli while asleep, just as humans do not respond to a phone call when they are napping.

Fruit flies and humans even react to caffeine similarly. When scientists give flies caffeine, they remain active for most of the day, just like humans do when they drink coffee, Joiner said. Flies, like humans, need a set amount of sleep.

PREVIOUS PAGE: *The word "circadian" comes from the Latin word "circa," meaning approximately and "diem," meaning day. Our internal circadian clocks as well as environmental factors, such as light, influence human sleep patterns. (Photo illustration)*

LEFT: *Studies have shown that even in the absence of light and other environmental factors, plants and animals have an internal clock that tells them when to do specific actions. With the help of its circadian clock, this dwarf fireweed releases wind-dispersed seeds at precisely the right time to ensure successful reproduction.*





ABOVE: *The first "clock gene" was found in fruit flies in 1972. By starting small, researchers hope to gain a better grasp on how the biological clock functions in humans and other animals. (Scanning electron microscope image. Fruit fly sample prepared by Western Washington University professor Dr. Sandra Shultze.)*

ABOVE RIGHT: *Cyanobacteria are microorganisms that researchers have used to make major discoveries about the circadian clock. Researchers found a gene in the bacteria that if mutated, alters their ability to detect change in light, which is used to synchronize their internal clock. (Scanning electron microscope image courtesy of Western Washington University Freshwater Algae Bioindcators class 2012.)*

"If you pull an all-nighter, the next day you are going to feel more tired, and you have to sleep more or more deeply to make up for that loss," Joiner said. "That is true for the flies as well."

While evidence has shown circadian clocks operate independently from environmental stimuli, a study on owl monkeys by University of Washington biology professor Horacio de la Iglesia suggests environmental factors have a part to play.

The owl monkey is a nocturnal animal. The clocks of owl monkeys are predominantly set for active nights and sleepy days. However, other external factors such as moonlight and temperature can override the clock's command, de la Iglesia said.

During the new moon, owl monkeys were inactive at night and active during the day instead. Even in optimal moonlight during the monkeys' active circadian period, cold weather can also alter their sleeping patterns, he said.

"Say that it is a full-moon night, but it is extremely cold. Because these animals are relatively small, they cannot be active in cold weather," de la Iglesia said.

Depending on the temperature and the amount of moonlight, owl monkeys are nocturnal during the summer and diurnal during winter, and they are more active during the full moon than the new moon. This study illustrates how the environment can sometimes drive the circadian rhythm.

Although the circadian clock requires light to reset, blind people's clocks work perfectly, said John Woodland Hastings, professor of molecular and cellular biology at Harvard University.

According to the Brown and Robinson article published in 2008, blind people can still use their eyes to synchronize light to reset their clocks. All rod and cone photoreceptors — the cells that enable us to see — are gone from the eyes, but melanopsin cells, specialized receptors that independently sense light, are present. Scientists theorize these cells send a signal to the master circadian clock in the brain.

"They cannot feel the light, but their circadian clock can," Hastings said.

According to a 2007 article in Dialogues in Clinical Neuroscience written by Steven Lockley and his colleagues, circadian clocks no longer function in people who are considered totally blind.

These individuals are unable to reset the clock due to an absolute inability to sense light. Without light, circadian clocks kick into a free-running system where they cycle without interference from the environment.

Initially, the clock will appear to run on the same schedule. However, the human rhythm can be slightly longer or shorter than 24 hours, so little by little the sleep-wake cycle in totally blind people will slip out of phase. Eventually, the person may sleep during the daytime, which can cause insomnia.

"If you abolish the circadian clock in an animal, that animal will still sleep, but the timing of its sleep will be messed up," Joiner said.

According to Lockley's article, many totally blind patients suffer from never-ending jetlag and have difficulty staying awake during the day, sleeping at night and focusing at work.

The study of circadian rhythms is essential for scientists to understand a foundational mechanism in biology. The research is basic and is not conducted specifically to solve problems but to understand the world, Hastings said.

"We live in a society where we think we can keep going 24 hours a day, and we are probably suffering from that," Golden said. "We need to know enough of how the clock works in people to understand what kind of intervention can be used to make our biology compatible with the lifestyle that we want to have."

NONTAWAT THAMMAWAN is a junior studying public relations, communication and psychology at Western Washington University. In his leisure time he enjoys playing badminton, dancing, cooking and reading creepy articles about the human brain.

BRENDAN WELLS is a junior studying environmental stewardship and activism at Fairhaven College. He is an avid whitewater kayaker who spends his free time documenting kayaking adventures and environmental issues through film and photography.

MAGNETIC **MINDS**

STORY KAYLEE SALSBURY | **PHOTOS** BRENDAN WELLS

When salmon smolts leave their freshwater homes behind, they become travelers in the vast, open ocean. A lifetime later, when they are ready to breed, adult salmon are drawn back to their home rivers like steadfast compass needles swinging north.

UNTIL ABOUT SIX YEARS AGO, BIOLOGISTS believed salmon used their strong sense of smell and the sun to find their way back to their natal area after spending years at sea.

In addition to these methods, scientists now think salmon are using the Earth's geomagnetic field as a compass to navigate to their birthplace.

Female salmon lay their eggs in the fall. After hatching in the winter, young salmon will spend one to three years in freshwater before swimming downstream to the ocean.

From there, salmon will spend six months to five years in the open ocean before using the magnetic field to find their way home.

According to a 2008 geomagnetic imprinting study written by Kenneth Lohmann, a professor of biology at the University of North Carolina, animals such as salmon return to reproduce in the same geographic area where they originated — a behavior known as natal homing.

"Animals start out in one part of the world, migrate a long distance and somehow return to their home area to reproduce," Lohmann said.

If a salmon deviates from the most direct route back to its spawning ground, it wastes time and energy, increasing the likelihood that it will die before reproducing, said Nathan Putman, a postdoctoral researcher from Oregon State University.

Disoriented males become less competitive when finding female companions while females have less energy and are not as competitive when finding a place to spawn, Putman said.

A fish using the magnetic field to home precisely has a better chance at breeding successfully.

THE GEOMAGNETIC FIELD

According to the 2007 study, Migrations of Salmon and Sea Turtles, written by Putman and his colleagues, the Earth's magnetic field resembles a dipole field, or a closed circulation of electric currents.

There is essentially a magnet running through the center of Earth with the south end near the North Pole and the north end near the South Pole.

The field is generally stronger as salmon get closer to the North Pole and weaker toward the equator, Putman said.

According to Lohmann's 2008 study, sea turtles use the magnetic field to find their way home after being released off the coast of Florida.

The earth has gradients within its magnetic field that change in strength in a given direction. Salmon in the open ocean are able to sense these changes and orient themselves toward home.

As salmon get closer to their home stream, their sense of smell becomes more important in finding their exact birthplace.

According to the 2008 study, salmon may detect the magnetic fields by using crystals of magnetite, an iron-rich mineral in their brains, which function as a receptor to the field.

However, there is no experimental evidence to back up this theory.

ABOVE: *Millions of young coho salmon are raised at the Skookum Creek Fish Hatchery. About 3 percent of these fish will return back to the hatchery years later.*

TOP: *Josie Kamkoff removes the tag from a coho salmon. Each tag tells when the fish was raised and released from Skookum Creek Fish Hatchery in Acme, Wash. Thousands of coho return to the hatchery each year, but researchers are investigating whether the metals in hatchery structures affect salmon's ability to navigate using the magnetic fields.*

PREVIOUS: *A young steelhead trout swims in a tank at Bellingham's Marine Life Center. Steelhead are in the same genus as Pacific salmon species.*

CONDUCTING THE STUDIES

When conducting studies to see how salmon used the magnetic fields, Thomas Quinn, a professor at the University of Washington School of Aquatic and Fishery Sciences, caught sockeye fry during their migration out of lakes and put them in test tanks.

Though the salmon were free to move in any direction, the fish had a tendency to swim in the same direction, Quinn said.

Quinn then put a copper wire in the tank and ran a direct current through it in order to reverse the magnetic field.

"We essentially turned magnetic north into magnetic south, and magnetic west into magnetic east in the area where the tanks were," Quinn said. "And then the fish headed in a different direction."

HOMING TO THE HATCHERY

Currently, Putman is conducting studies to see if farmed fish born in hatcheries have trouble homing.

Hatcheries are typically made of many unnatural materials such as electric wires and metal nets, which will affect the perception of magnetism, Putman said.

The pools at the Skookum Creek Fish Hatchery, holding more than 1 million coho salmon, are made of asphalt, said hatchery manager Bill Finkbonner.

The hatchery raises salmon for about 18 months before releasing them into the wild. From there, the salmon spend six months to three years in the ocean before coming back as adults.

From the 1 million to 1.6 million salmon born in the hatchery, about 50,000 return with a quarter-wire tag. The tag tells where the fish was released, caught and where it has been, Finkbonner said.

"From a navigational perspective, the salmon need to be precise," Putman said. "They need to know where they are, where they are going and the most efficient way to get there, and the magnetic field allows them to do that."

The salmon that successfully find their way back to their birthplace pass their homing skills onto their offspring, Putman said.

As future generations of salmon swim out into the big open ocean, they will use their fine-tuned homing skills in order to find their way home, just like the generations before them. Soon scientists may be able to detect how the internal compasses of salmon succeed in bring ing generations of salmon home year after year.

KAYLEE SALSBURY is a senior studying public relations with a minor in communications at Western Washington University. When she is not studying, she can be found hiking or in the kitchen.

BRENDAN WELLS is a junior studying environmental stewardship and activism at Fairhaven College. He is an avid whitewater kayaker who spends his free time documenting kayaking adventures and environmental issues through film and photography.

MOUNDS *OF CONFUSION*

STORY BETH CARLSON | **PHOTOS** CONNOR GRIESEMER

Pocket gophers. Retreating glaciers. Native American burials. Permafrost. Seismic activity. Ant colonies. Suckerfish nests. Paul Bunyan's shovel. The bathwater of a mythical bird.

Hundreds of hypotheses and centuries of tall tales attempt to explain the origins of the mima mounds, located just southwest of Olympia, Wash. The explanations range from the outlandish to the sensible, but the mounds remain an enigma.

An interpretive center sits in the maze of mounds and serves as hub for curious visitors.

FROM AN AERIAL VIEW, THE 637-ACRE MIMA Mounds Natural Area Preserve looks as though an invisible hand plucked away a patch of feathers from the Earth, revealing goose bumps underneath. The mounds vary slightly in size but are up to 6 feet tall and 30 feet in diameter. The pimpled landscape appears all around the country, but Washington's mima mounds are where the phenomenon was first studied scientifically.

A cross-section of a mound shows it is composed of black, fine-grained topsoil. Underneath the topsoil, a layer of dry, rocky gravel remains level. Normally in hills, the gravel layer ebbs and flows with the top layer, while in mima mounds, the gravel layer is flat. Scientists remain unsure how these mounds, made from only topsoil, could have remained for thousands of years.

Since the early 19th century, the question of the mounds' origin has captivated scientists, including Tim Walsh, a geologist for the Washington State Department of Natural Resources. However, Walsh and other modern scientists have an advantage over their 19th century counterparts — new technology.

SCULPTED BY ICE

Using laser-mapping technology called LIDAR, Walsh and geologist Robert Logan found evidence to support a claim first made by J. Harlen Bretz 100 years ago.

Bretz noticed the mounds are not symmetrical — they lean north. This got him thinking. Retreating glaciers formed the Puget Sound prairies. As glaciers melted, the area flooded and froze over. Sun cups, or concave indents, formed in the sheet of ice covering the area. Bretz figured wind or floods filled the cups with debris. When the ice melted, it left behind debris in the shape of the mounds seen today.

Logan and Walsh were the first to use LIDAR to study the mounds. After analyzing their maps, they found similarities between the mima mounds and the geology left behind by swiftly retreating glaciers — evidence that Bretz may have been right.

The word LIDAR is a combination of "light" and "radar." A LIDAR instrument points a laser at an object — in this case, the mounds — and determines how far away that object is by measuring how long it takes for the beam to bounce back. It works a bit like the echolocation of bats.

Using this technology, Walsh and Logan created an exceptionally accurate topographi-

TIMELINE OF MIMA MOUND FORMATION HYPOTHESES

KEY

DATE

Author

Hypothesis

Pre-European settlement: Local Native American tribes set fire to the prairies to maintain the growth of their crops.

According to native legends, the mounds are the hide of a giant bear or lion.

1845

Wilkes

Lt. Charles Wilkes, leader of a U.S. expedition, believes the mounds were created by Native Americans; he says they "bear the mark of savage labor."

1873

Hilgard

German-American soil scientist Eugene Hilgard believes the mounds are anthills.

1000 B.C.E.

Glacial outwash forms prairies

1855

Agassiz

Swiss biologist Louis Agassiz believes mounds are suckerfish nests, based on second-hand descriptions and drawings.

1906

Farnsworth

Scientist P. J. Farnsworth believes a severe storm uprooted trees. These trees decayed and eroded into mounds.

cal map, allowing them to see the mounds more clearly than ever before.

According to the study Logan and Walsh published in 2009, if the glaciers formed the mounds, the glaciers would have retreated 25 miles in four to five years or possibly even in one season.

But the evidence does not apply to mounds everywhere, Walsh said.

"It is a mistake to equate [Puget Sound] mounds with other mounds unless you can show they have the same origin and the same morphology," Walsh said. "There are a number of ways mounds can be made."

MOVEMENT BY ANIMALS

While LIDAR shows an accurate view of the current landscape, geologist Diana Johnson said the true answer lies in how the mima mounds have changed over the years.

"LIDAR is one moment in time — the present time," Johnson said. "You can find all the mima mounds all over the landscape, but it does not tell you how or why they are there."

Diana and her husband, geologist Don Johnson, studied the changes in mima-like mounds around the country for about a decade and found a common factor at each site: burrowing animals such as pocket gophers.

The theory that burrowing animals may have moved soil into mounds is not new. The idea first arose in 1941 when vertebrate zoologists Walter Dahlquist and Victor Scheffer hypothesized that the center of a mound was once the center of an animal's dwelling. The Johnsons, both interested in soils, expanded the idea as Diana was gardening in her backyard.

Around 1970, Diana uncovered a loose, un-grouted brick patio about 9 inches under the surface of her garden's soil. The bricks were laid down when the house was built, right after World War II. The couple left for the summer, but when they returned to the yard three months later, the patio's loose bricks were covered up once again.

"If we can understand how this got buried, maybe we can understand how other things are moving around in the soil," Diana said.

The first clue they noticed was remnants of burrowing insects, such as ants and worms, on the surface of the soil. With this in mind, the couple visited the Mima Prairie. Looking at

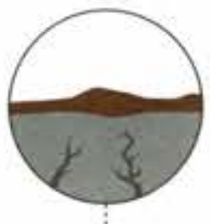
ABOVE LEFT: *Mima Mounds Natural Area Reserve is just south of Olympia in Littlerock, Wash. The park stretches 637 acres across a puzzling landscape, littered with sporadic mounds approximately 6 feet tall and 30 feet wide.*

ABOVE RIGHT: *Year-round, visitors can explore the trails that weave through the Mima Mounds Nature Reserve and ponder the formations for themselves. Pockets of similar mounds can be found as far east as the Mississippi.*

ABOVE: *A dissected mound shows layers of soil on top of glacial till, which consists of mixed rocks deposited by receding glaciers. The upper level of topsoil gives the mounds their distinct shape. Unlike a normal hill, the underlying till does not follow the contour of the topsoil.*

1913
Bretz

J. Harlen Bretz, celebrated geologist, suggests the mounds were formed by sun-cups in ice.



1989
Berg

When hammering on a piece of wood covered with ash, geologist Andrew Berg notices the ash piling up in small mounds, leading him to believe seismic activity may have formed the mounds.

2012
Johnson

Donald Johnson publishes a book of studies that all point to burrowing animals as the creator of the mounds.

1942
Dalquest

Walter Dahlquest visits the mima prairie and hypothesizes that they were formed by pocket gophers

2009
Logan and Welsh

Geologists Logan and Walsh become first to study the mounds with LIDAR, reinforcing Bretz's sun-cup idea.

a cross-section of a mound, they found a layer of larger stones underneath the topsoil, not unlike the patio they unearthed in their backyard.

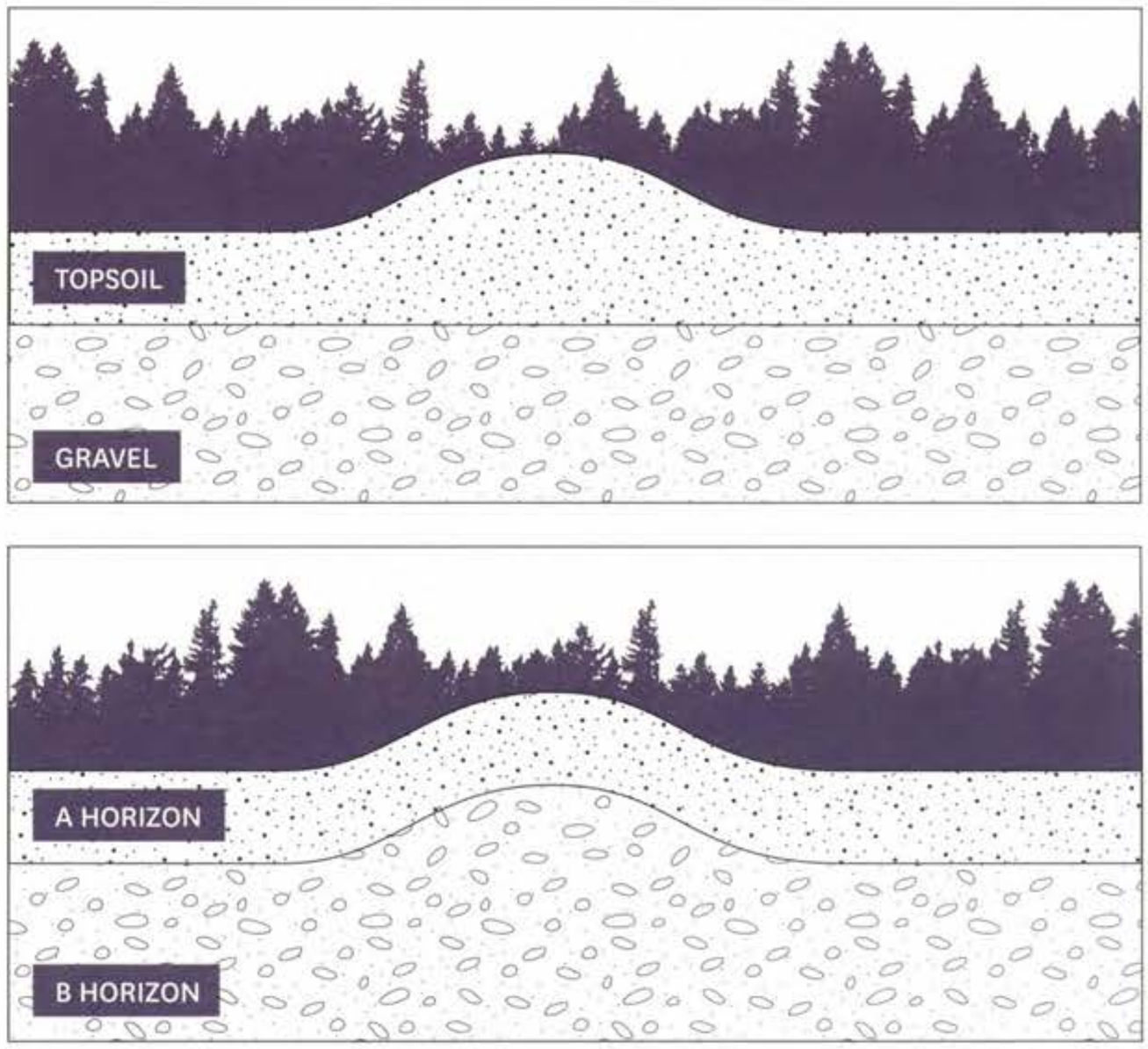
Understanding how burrowing animals affect soil is essential to understanding the formation of the landscape, Diana said.

"Soils are a part of the landscape," Diana said. "In fact, they are like the skin of the landscape."

But some scientists, such as Walsh, are still skeptical.

Gophers and other burrowing animals would not be able to tunnel through the big rock layer, so the larger stones and gravel would stay at the bottom while the fine-grained soil would be near the surface.

"This soil is blackened from field burning," said Walsh. "If gophers were down below and were pushing gravel up, you would have some of the unburned gravel mixing in with the burned soil. But there is not any."



ABOVE: *The mima mounds were formed with a curved A horizon, and a flat B horizon, which is not a normal occurrence in nature.* **BELOW:** *Normally when the earth moves the gravel layer below pushes up on the fine silt above, and creates a swell in the earth's surface.*

A LANDSCAPE SUSTAINED BY FIRE

For thousands of years, Native American tribes, such as the Chehalis, used controlled burnings to maintain the Puget Sound prairies, ethnoecologist Linda Storm said. These communities used fire to maintain the prairie and promote the growth of their favorite crops, chiefly the wildflower camas.

"Without fire, without management, the land would become covered with forest, and ultimately the mounds themselves would decay," Storm said.

Local tribes used the mounds like raised garden beds. Because different plants grow better on various sides of the mounds, tribes were able to extend the harvest season and promote diversity in their crops. When the weather was dry, the troughs between the mounds retained water to nourish plants.

"Scientists remain unsure how these mounds, made from only topsoil, could have remained for thousands of years."

According to a book published in 1991 by Arthur Kruckeberg, professor emeritus of botany at the University of Washington, when European settlers first discovered the mounds, they assumed native people created them. That theory is largely discredited now since little archeological evidence been found on the mounds.

Although they did not create the mounds, the local tribes had their own ideas on how they formed. The Chehalis tribe called the prairie nsq'wanxtn, a word for a frame to stretch animal hide. According to legend, a gigantic animal threatened to destroy all people as the Earth was taking shape. Once the tribe slayed the monster, they stretched its dark hide across the prairie, explaining the mounds' dark soil.

The Department of Natural Resources still performs small controlled burnings on the mima mounds to combat invasion of nonnative Scotch broom, said Birdie Davenport, the Mima Mounds Natural Area Preserve site manager. Larger burnings are not as practical anymore because nearby development could be damaged.

As a result, only 3 percent of the prairies around south Puget Sound that once stretched across 180,000 acres remains.

Even as scientists are honing in on an explanation for the mounds, the prairie's mystery attracts visitors, Davenport said. She encourages those visitors to consider current science rather than settling on the first theory they hear.

"There is a benefit to having something be unknown," Davenport said. "There are a lot of interesting scientific questions that have not been resolved and the mima mounds are a great example of that. Even a third-grader can go out there and marvel at it and wonder about it."

BETH CARLSON is a junior studying journalism and international relations at Western Washington University. When she is not pursuing her love of writing, she is usually out exploring the gorgeous Pacific Northwest.

CONNOR GRIESEMER is a visual journalism major and internet resource creation and management minor. Other than photographing for The Planet, he enjoys surfing, skiing and enjoying life in the great outdoors.

FEATURED MULTIMEDIA STORY

URBAN CANOPY CLIMBING

Up above in the forest canopy, an array of species, from leafy epiphytes to birds and amphibians, await the city-dwelling tree climber. See how climbing trees can give new insights into what lies overhead in urban forests and their importance to us.

STORY & VIDEO Ryan Hasert and Brendan Wells

ONLINE EXCLUSIVES

ADAPTIVE FARMING

STORY Madalynn Gavigan Martin
PHOTO Connor Griesemer

WASHING ASHORE

STORY McKenna Moe
PHOTO Philip A. Dwyer (*used with permission of The Bellingham Herald*)

FOR MORE

Visit the Planet website at **http://planet.wwu.edu** for exclusive online stories, additonal photographs and other content.

“Science is not meant to cure us of mystery,

but to reinvent and reinvigorate it.”

- Robert Sapolsky