SAGE

A PUBLICATION *of the* YALE SCHOOL *of* FORESTRY & ENVIRONMENTAL STUDIES

A global band of scientists, artists, and storytellers gather data to help create a wildlife refuge larger than Yellowstone

PRAIRIE HOME COMPANION

PLUS

Scientist-Soldiers Deployed in Iraq

Canines Who Sniff Out Endangered Species

The Other Galapagos

SAGE

ON THE COVER

Photograph by MORGAN CARDIFF

The Sacred Headwaters or Klappan Valley in British Columbia is the source of the Klappan, Nass, Skeena, Spatsizi,and Stikine Rivers and the site of a major fight over energy development.

Photograph by **PAUL COLANGELO**

Our Bounded World

The boundaries we create shape our perceptions of the world, each other, and, ultimately, ourselves.

AS A YOUNG ECOLOGIST working in the temperate rainforests of the Pacific Northwest, I was fascinated by the huge, fallen trees, blanketed with soft mosses, resting on the forest floor. Ferns and saplings stretched skyward from these fallen trees, commonly called "nurse logs." Scanning the forest, you'd see nurse logs in various stages of decomposition, each nursery supporting a colonnade of young trees. Their roots hugged the nurse log as they reached for the soil below. Over time, the earth would slowly absorb the decaying nurse log. Or, the nurse log would become the earth. It was hard to tell. In fact, the boundary between life and death itself often appeared indistinguishable.

This issue of *Sage* explores some of the environmental boundaries that define our world. Boundaries, whether physical or conceptual, have real consequences. Jesse Lewis' piece, "Wallace's Line," shows how geographic boundaries can lead to the evolution of new species. In "Fracking Across State Lines," Samantha Ostrowski reports on how political boundaries safeguard environmental quality and public health.

But boundaries are not always so clearly delineated. Kaitlin Stack Whitney describes how conservation canines are pushing scientists to question the nature of their research in new and unexpected ways. Sarah Barbo's memoir of her military service in Iraq reveals her struggles with what it means to be an "environmentalist." These are difficult and complex questions. And how we answer them shapes our notions not only of the world, but also of ourselves.

As in the case of the nurse logs, environmental boundaries can be difficult to see. Likewise, it can be difficult to talk about varying environmental perspectives. But we need to continue to explore these issues. We, at *Sage*, strive to "expand environmentalism" by promoting more meaningful conversations about our world and our places in it.

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Editor-in-Chief

SAGE

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SACRED HEADWATERS AND RICH COAL DEPOSIT

Environmentalists and First Nations work together to save the sacred in Canada's Pacific Northwest

By EMMELINE MOLNAR

Anthropologist and conservationist Wade Davis has said the question is not whether development should happen, but whether it should happen in the Sacred Headwaters.

ON NOVEMBER 28, 2014, the government of British Columbia issued an extended order to safeguard, temporarily, the Klappan Sacred Headwaters, a place of ecological diversity and spiritual importance for many Canadian First Nations. Specifically, the order defers mining permit verdicts and newly proposed tenures until March and December 2015, respectively, in effect placing a moratorium on mining.

Photograph by **PAUL COLANGELO**

Estimated annual value of the Skeena River Watershed wild salmon economy **$110 million**

Grizzlies, moose, caribou, and wolves roam the the forests of the Sacred Headwaters.

Amid towering mountains in northern British Columbia, the Klappan Sacred Headwaters is a hallowed place where the Tahltan Nation and its communities of some 50,000 people dwell. Some First Nations avow these headwaters are where Raven, a magical creature in indigenous mythology, created the world. The area also hosts irreplaceable predator-prey relationships and is the meeting point for the Skeena, Nass, and Stikine Rivers, three of Canada's most valuable wild salmon watersheds. Resistance against industrialization of the area has united indigenous, environmental, and human rights activists.

"Under a threat, it is amazing what alliances can be built...and built strongly," says Nathan Cullen, New Democratic Party Member of Parliament for Skeena—Bulkley Valley. In 2012, such groups considered Royal Dutch Shell's abandonment of its plans to use the area for coalbed methane fracking a victory, but many believe the area is still in jeopardy, given the recent proposals for mines and liquefied natural gas pipelines.

Despite such "unanimous opposition of any industrialization," mining initiatives continue to threaten this area, says Shannon McPhail, Executive Director of the Skeena Watershed Conservation Coalition. The area is exceedingly rich in mineral and energy resources, and the region's value as an intact ecosystem is juxtaposed against its multi-billion dollar economic valuation. McPhail praises the newly imposed sanctions, as they will "allow for negotiations and meaningful conversation."

Bruce Hill, Project Director at Headwaters Initiative, believes the province could go further. He notes, British Columbia, through an Order in Council, "could declare the Sacred Headwaters protected in a matter of minutes."

On the prospect of securing and protecting the cultural values of the area, Stan Tomandl, board member of Sierra Club BC, believes what's called a "tribal conservancy" would be more ideal for continued protection of not only the area, but also First Nations people's rights. Tailored to the Tahltan communities' specified interests, a tribal conservancy would ensure the preservation and protection of First Nations' cultural values and uses, as well as protect the surrounding biological diversity and natural environment. Cooperative negotiations between First Nations and the province establish the conservancies' individualized management.

In the absence of any such protections, McPhail warns that the risks are real. She says exploiters could reduce heritage land to "waste rock piles." "If that isn't a violation of human rights," she says, "I don't know what is."

Photograph by **PAUL COLANGELO**

Energy

FRACKING ACROSS STATE LINES

When it comes to natural gas, how deep do state borders go?

BY SAMANTHA OSTROWSKI

IN DECEMBER 2014, Joe Martens, New York Department of Environmental Conservation Commissioner, announced that the state would continue to prohibit high-volume hydraulic fracturing, or fracking, a controversial drilling technique. The decision followed the release of a report by the state Department of Health citing potential risks to human health.

"Would I let my family live in a community with fracking?" Howard Zucker, Department of Health Commissioner, asked in a press release. "The answer is no. I therefore cannot recommend anyone else's family to live in such a community either," he said.

Nearby in Pennsylvania, the outlook for fracking is very different. The state is an epicenter of renewed interest in the vast quantities of natural gas contained within the previously inaccessible Marcellus Shale. Leasing speculation began in 2003, largely beneath residents' radar, and drilling has only boomed since. When I traveled through the state in 2012, many residents, including those who eagerly leased their land, characterized the rapid industrialization of largely rural landscapes as the colonization of the "wild west."

Centuries-old regulations from the coal era of the 1800s prioritizing mineral extraction over surface uses have supported widespread drilling in the state. Many individuals I met balanced concerns about the impacts of drilling on the environment, the economy, and lifestyles against the possibility that the water could go bad anyway, whether or not they leased their land. Those who did not own mineral rights, which U.S. common law separates from surface rights, felt particularly helpless.

"Would I let my family live in a community with fracking? The answer is no."

Three years later, amid changing political and economic climates, accumulated experience with drilling, and emerging research on the impacts of fracking, Pennsylvania has taken a few steps in the direction of its northern neighbor. The November 2014 gubernatorial election of Tom Wolf against incumbent Tom Corbett signaled the possibility for change—or at least an opening for discussion about the future of drilling in the state. Wolf distinguished himself against his predecessor by favoring stricter taxation and regulation of the hydraulic fracturing industry. Less than two weeks after his inauguration in January 2015, he reinstated a moratorium on drilling in state parks and forests, a ban that Corbett's administration had lifted.

Despite these shifts across both states, some Pennsylvanians expect little impact on the occurrence of shale gas development in their communities. Ruth Tonachel, a landowner in Bradford County who has grown increasingly thankful that she did not lease her mineral rights, commented: "I was glad for New York, that the decision was made, but it doesn't do us any good. ... Now we really are a sacrifice zone."

Similarly, Raina Rippel, Director of the Southwest Pennsylvania Environmental Health Project, expressed concern over the lack of information about the long-term impacts of fracking, and over the extent to which local communities remain unprepared to handle drilling-related emergencies that have and will continue to arise. "I don't think that the attitude we've seen in New York translates into Pennsylvania," she said. "An attitude prevails which says we can do this, we can do this safely, we can do this in an environmentally-conscious way."

Fracking is now a part of the Pennsylvanian landscape, and though the pace of development has slowed in certain areas, it shows no signs of going away anytime soon.

The states' divergent policy decisions exemplify the pervasive sense that everyone is either for or against fracking—a sense heightened by advertising campaigns, media blasts, and public forums that seem to provoke more ire than provide spaces for weighing the benefits and risks of drilling. Even environmentalists argue about the climate benefits of natural gas as an energy source, versus the potentially devastating long-term effects of groundwater contamination and landscape conversion.

These decisions are actively framing debates about alternative energy, its local development, and its consequences on the health of people and ecosystems. Northern Pennsylvania and southern New York may be separated only by a geopolitical boundary, but their landscapes are facing very different futures.

Illustration by **LISA NOWLAIN**

Number of chemicals found in streams near osprey nests around Chesapeake Bay **18**

Overmedicated Osprey

You probably think you're the only one taking drugs prescribed for you. You're not.

By DEBI McCARTHY

CLEARLY, NO ONE prescribes blood pressure medication to wild birds, but a field study, recently published in Integrated Environmental Assessment and Management, found low concentrations of diltiazem in osprey chicks around the Chesapeake Bay.

"Osprey are an excellent sentinel [species] for monitoring contaminants in the environment," says Rebecca Lazarus, a researcher at University of Maryland, College Park, who led the study. Because they live near people and eat at the top of the food chain, past osprey exposure to DDT, mercury, lead, and other contaminants warned of risks to people as well as wildlife. These birds are particularly vulnerable because they nest on rivers that receive treated wastewater from Baltimore and Washington, DC. Many treatment plants are only able to eliminate about half of pharmaceuticals and personal care products present in wastewater before releasing the treated water into streams.

For three years, each summer and spring, Lazarus and her colleagues identified osprey nests around the Bay, taking blood samples from one seven-week-old chick from each nest and from their parents' favorite fish prey nearby. They found traces of diltiazem in each of the 69 osprey chicks that they tested.

Despite finding 18 chemicals in streams near the nests, the team detected only eight chemicals in fish and only diltiazem in the birds. The other chemicals in the nesting streams included analgesics, antibiotics, a blood anticoagulant, an anti-seizure medication, antihistamines, stimulants, blood pressure medicines, anti-inflammatories, a cholesterol drug, an artificial sweetener, and caffeine.

Kathryn Arnold, Research Fellow at the University of York, who was not involved in the project, called the work an "important study" for tracing pharmaceuticals through a food chain. At each stage, from water to fish to osprey, the concentration of diltiazem increased. As fish are repeatedly exposed to diltiazem, they absorb and retain it in their fat; the diltiazem concentrates in osprey's fat when they eat contaminated fish.

"At this point, there is no information on how these pharmaceuticals affect piscivorous [fish-eating] wildlife including osprey," Lazarus says, because there are so few studies. In people, diltiazem restricts the flow of calcium into cells surrounding the heart, causing the arteries to relax and the heart to beat less forcefully. Medications designed to work for humans at low concentrations can affect animals, especially vertebrates, Arnold says, because their bodies work similarly to humans. In a rare case of lethal side effects, three species of vultures in India are now on the verge of extinction after consuming cow carcasses that contained diclofenac, an anti-inflammatory.

Lab experiments on fish suggest that such unintended medicating can change activity level, aggression, boldness, sociability, and appetite. Depending on the medicine, chemicals can also lead to feminization and changed reproductive behaviors. Researchers have found that starlings who consumed insects treated with fluoxetine—commonly known as Prozac—exhibited altered brain development, decreased appetite, impaired immune systems, and a reduced libido.

When research on pharmaceuticals in the environment began in the 1990s, scientists focused on whether medicines were even present in freshwater aquatic systems. Within a decade, however, researchers began to identify specific pharmaceuticals in streams, fish, insects, amphibians, and even the algae coating the rocks on river bottoms. This latest research suggests that a wastewater chemical cocktail could be an additional stressor for wildlife in aquatic environments.

Illustration by **AUTUMN VON PLINSKY**

LANDMARK ADVENTURE SCIENCE ON THE GREAT PLAINS

BY EMILY STIFLER WOLFE

A DEDICATED GROUP OF RESEARCHERS IS WORKING TO PROTECT VITAL PRAIRIE HABITAT FOR BISON, PRONGHORN, AND MORE THAN 70 OTHER SPECIES OF WILDLIFE.

Landmark volunteers walk a transect during the May 2014 training. The crews collect wildlife and habitat data on the prairie year-round, walking 8-10 miles a day in the 100-degree heat of summer, and below-zero winter weather.

Photograph by **MIKE QUIST KAUTZ**

With each step,

we feel the pulse of the land, echoes of the great herds that once roamed the high plains.

We are the Adventurers and Scientists for Conservation Landmark Crew, a band of scientists, artists and storytellers from around the globe gathering environmental data to support the creation of a wildlife refuge larger than Yellowstone.

The American Prairie Reserve lies on a windswept steppe just south of the Montana Hi-Line and east of the Little Rocky Mountains. Our ASC researchers hike transect parcels of the reserve and traverse its fence lines, crossing sagebrush plains, skirting sprawling prairie dog towns, and watching bison run along broad ridgelines.

A multi-year partnership between ASC and the reserve, the Landmark project gathers data on elk, mule deer, pronghorn and more than 70 other species that live here—vital information that reserve management uses to improve habitat and restore healthy wildlife numbers.

Summer Landmark crews live the field, experiencing the elements firsthand. Here, a late-summer lightning storm tears across the prairie a few miles from camp.

Tomás Ward of the February 2014 crew scans the horizon for wildlife.

Crewmember Lindsay King and crew boss Ryan Rock check a camera trap on the reserve's Sun Prairie parcel. These motion-triggered cameras film wildlife interactions with reserve fences.

Photograph by **MORGAN CARDIFF**

Photographs by **ASC PHOTO** *(top right) and* **EMILY STIFLER WOLFE**

The reserve's long-term goal is to create a 3.5-million-acre wildlife reserve, the largest in the lower 48 states. In 2014, the project's first year, Landmark volunteers recorded more than 12,900 wildlife sightings.

Looking west at sunset over the Little Rocky Mountains.

Photographs by **MIKE QUIST KAUTZ** *(top) and* **MORGAN CARDIFF**

Crewmembers Morgan Cardiff and Christin Jones relax on a day off in one of the reserve's yurt camps. Six volunteers reside together as part of the Landmark program, forming close bonds as they live and work together.

The reserve is home to a growing herd of nearly 500 plains bison, classified as livestock in Montana but managed as wild. ASC volunteers often wake up in the morning with bison surrounding them, scratching against the tent platforms.

Photographs by **ERIK GOLDSTEIN** *(top) and* **MORGAN CARDIFF**

In late August, one storm dropped eight inches of rain—more than half the area's average annual rainfall. Landmark crewmembers often describe this place of stark beauty and severe weather as a "land of extremes."

Learn more about the Adventurers and Scientists for Conservation Landmark crew at

www.adventurescience.org/landmark

Photograph by **MORGAN CARDIFF**

NATURAL SECURITY

IN THE MIDDLE OF A WAR ZONE, AN AMERICAN SOLDIER BATTLES DIRTY WATER, DUSTY AIR, AND BLACK FLIES, AND COMES HOME A CHANGED ENVIRONMENTALIST

BY SARAH BARBO

PREVENTIVE MEDICINE SOLDIERS COLLECTING WATER SAMPLES FOR TESTING AT THE SHATT AL-ARAB RIVER IN BASRA.

Photographs courtesy of **SARAH BARBO**

THERE WAS A COW COMING TOWARDS US in the river. As she moved closer, I spotted other cows wading behind her, nibbling on the river grass. After nine months in Iraq, I had become accustomed to the surreal. The Army specializes in making the outrageous seem doable and, before you know it, you find yourself running in snow so thick you can't open your eyes; or throwing yourself into a mud pit; or careening out of an airplane. No time for reflection. You just do it. Iraq was all that – magnified. Yet, the cow swimming towards us caught me off-guard. Cow hazards had not been a part of our training.

It was spring 2009. My team stood knee-deep in the Shatt al-Arab River in southern Iraq, gathering water samples for testing. Our forward operating base relied on the Shatt al-Arab for its water supply, and we needed source samples to establish a pre-treatment baseline for quality.

The military trains environmental scientists and preventive medicine specialists to keep soldiers in the fight by protecting them from environmental hazards. While my fellow combat brigade soldiers conducted infantry and logistics missions, I tested the water and air, inspected food, trapped insects, and issued reminders about the importance of hand washing.

JOURNAL ENTRY, OCTOBER 2006

"My plans for Army life after college and ROTC included hardcore physical training, leading medics, running medical operations in the field. For the preventive medicine course today we went on a field trip to a water treatment plant, learning how to turn poop water into something reasonable. Um, what? Not what I signed up for."

CITING MY BIOLOGY BACKGROUND and the "needs of the Army," I was assigned as an Environmental Science and Engineering officer after graduation. It proved to be a natural role, though I did not realize it at first. I had expected to be leading combat medics, not risking my life testing water tanks. I was surprised and initially unenthused about my new assignment.

It's not that I was disinterested in environmental issues. Growing up, I reveled in the outdoors. Returning from a long trail run in the woods, I felt alive and invigorated. On summer days, my younger brother and I often hiked up the river in our backyard, turning over rocks and catching crayfish. The world was my playground.

The author in Basra, on the road again, waiting for a convoy out to another base. Deployment was characterized by frequent travel and some unusual combat travel items, like the pesticide sprayer shown here.

In college, coursework complicated that idyllic vision of nature. I studied the tragedy of the commons and witnessed water allocation struggles in Hawai'i. I advocated for conservation and recycling, earning the nickname "hippie of ROTC" from my Army classmates. For our senior roast, the ROTC student playing me wore flowers in her hair. I took it in stride. For me, identifying as an environmentalist translated into a deep-seated love for the natural world and a responsibility to mitigate our impact on it.

Once I graduated and commenced military training, however, I spent weeks learning about all the ways the environment can harm human health and, by extension, military operations. The Army systematically reshaped my view of the environment as a beautiful playground requiring responsible stewardship. Now, it represented a threat.

My brigade combat team deployed to Iraq in August 2008 and was tasked with maintaining security across the southern region. Platoons established outposts in old hotels, a former Olympic training center, an abandoned UN building, even a casino. The medical company was stationed at brigade headquarters outside the city of Al Diwaniyah, but I spent much of my time traveling and conducting camp inspections. Upon arrival at a new camp, my team and I would survey all the support systems on which soldiers depended. These soldiers shared similar concerns to those of any community – safe food, clean air, functional sanitation systems, drinkable water, and protection from disease.

JOURNAL ENTRY, APRIL 2009

"We are all over the place, inspecting possible mold in a tent, hunting down engineers responsible for the new eating areas, talking about field water concerns with combat commanders, ordering supplies, preparing for a meeting at the camp mayor office, determining the cause of a dysentery outbreak. No day is the same. Also – beautiful sunset tonight."

"WHAT'S THIS FOR?" I asked, pointing to a small space partitioned off from the Iraqi kitchen. My team was on a "goodwill" inspection. The cook walked across the stained tile floor, picked up a large knife, and brought it down with a thwack on the wooden table. "Butchering room," my interpreter relayed, somewhat redundantly.

Contaminated food was a major concern for my team; one bad meal could take out an entire platoon for a day or more. Dining facilities varied widely depending on the size of the camp. The Iraqi butchering room stood in stark contrast to the cafeteria grade kitchens we inspected on the larger U.S. bases. There, the stainless steel appliances smelled of bleach, but at the more remote outposts, cooks would give me a knowing smile and then lead me through the "kitchen" – a tent with a field range stove, pallets of dry food, and buckets for washing dishes. Standing inside, the tent's walls flapping as the wind rushed through, we'd discuss how best to keep mice out of the food and dust off the dishes.

MAJOR RIVERS OF IRAQ

THE SHATT AL ARAB forms at the confluence of the Tigris and Euphrates rivers.

Dust constantly hung in the air. When a massive sandstorm swept through the base, everyone knew to get inside. More insidious were the smaller, daily windstorms; soldiers could accumulate particulate matter in their lungs without realizing it. To monitor the air, we placed stations around the base that collected 24-hour samples of airborne particles, which we sent back to the States for analysis. We posted prominent signs explaining our testing. Environmental sampling in a war zone presents its own unique challenges; a briefcase with an audible motor sitting inside the camp perimeter looks a lot like an IED.

Waste disposal was another challenge. The large bases had either simple plumbing systems or Porta-Potties that local Iraqi companies serviced. At the smaller outposts, I found more temporary and basic setups: urinary pipes, seepage pits, and burn-out latrines. Burn-out latrines, oil drums sawed in half and burned each night using a combination of motor oil and gasoline, were favored for their practicality, both in design and function. The threat of burn-out duty – stirring the burning barrels until their contents were incinerated – served as an effective deterrent to bad behavior. At one outpost, American soldiers informed us that Iraqi soldiers had a habit of defecating on the ground along the perimeter of the post near the bunkers. The soldiers worried about sanitation, but also about their ability to get to the bunkers quickly without stepping on "land mines."

AIR, FOOD, AND WASTE required continual monitoring, but ensuring adequate water supplies represented, by far, my most critical concern. Soldiers in my brigade conducted dismounted patrols wearing boots, a helmet, and 50 pounds of body armor, often with temperatures hovering around 120 degrees Fahrenheit. The risk of heat-induced injuries was high.

I learned just how quickly the desert heat could take its toll during an inspection in Al Qurna, a city that sits at the confluence of the Tigris and Euphrates rivers. My team was at an outpost located in the city and surrounded by tall buildings. The degree of exposure compelled us to wear full combat gear while outside. Over the course of an afternoon, we traversed the outpost on foot, inspecting the water supplies, latrines, and motor pool where the vehicles were kept. Once finished, my soldiers and I flopped down inside an air-conditioned dining tent. The dehydration hit me with a rush. I downed two large bottles of water and a Gatorade, dimly realizing how close to heat stroke I had come.

Seven months into my deployment, our brigade relocated to Basra in the far south. The geographic change was reflected in the cuisine. Chicken and rice dishes predominated in Al-Diwaniyah, but in Basra, Iraqi police forces served us platters of whole fried fish and tuber vegetables, a testament to the region's ties to the Shatt al-Arab River. The river, which served as the primary water source for our Basra operating base, snakes south from the confluence of the Tigris and Euphrates, irrigates Iraq's ancient marshlands, flows through Basra, and eventually empties into the Persian Gulf.

Our base in Basra was the largest in the region and had the most extensive water treatment facility, replete with ROWPUs, or reverse-osmosis water purification units. These machines convert water from any source – even salt water – into potable water via a series of filters. This was a game-changer for the military. ROWPUs allowed us to operate in harsh, desert conditions without depending on shipments of bottled water from Baghdad. Field commanders stockpiled water like ammunition; every outpost featured a teetering pile of bottled water, stacked high on pallets placed prominently in the central living area. It was the one environmental health concern that the commanders worried about as much as I did.

With water also comes wildlife. Both Al Diwaniyah and Basra sit near large sources of water and, as a result, the birds were plentiful. Once, after reports of birds dying around the base, I was half-jokingly ordered to "kill all the birds" by my commander who feared a case of avian flu. Luckily, other issues superseded this one and it did not come up again. But the incident showed how easy it is to overreact to perceived threats while operating in an unfamiliar environment.

Insects presented the most serious wildlife threats. While malaria from mosquitoes posed no risk in Iraq, leishmaniasis from sand flies did. Leishmaniasis is a parasitic disease with symptoms such as boils or lesions on the skin, or in more serious cases, the mucosal membranes and internal organs. Sand flies are small enough to slip through the holes in mosquito netting, and the sandbags we stacked around the tents provided ideal habitat for the flies. We had to constantly balance the risks of spraying pesticide near sleeping quarters with keeping the sand fly population in check.

Charles Darwin had his finches; Jane Goodall her chimpanzees. I became associated with the ubiquitous, relentless black flies. Flies are bad for operations because they go straight from the latrine to the dinner table. Moreover, they swarm around the eyes, lips, or anywhere with moisture. My secret weapon was a special type of fly bag staked in the ground that held an irresistible fly attractant. Bins the size of grocery bags would fill up with fly carcasses, and though it barely made a dent, soldiers were cheered at the sight. I would arrive at bases to greetings like, "Do you have those fly bags?" I became so linked to them that by the end of the deployment my friends dubbed them "Barbo bags."

JOURNAL ENTRY, NOVEMBER 2008

"Faulty communication has caused us to miss our flight – next one is tomorrow. Now I've wasted another day. I can't help thinking of the futility of all of it. My mission is to get to these places for inspections, and I'm literally risking my life to do so. But what happens if we don't make it out to a place? Sometimes I think - um, nothing really."

OVER THE COURSE of the deployment, I often felt conflicted. As an environmentalist, I was concerned about natural resource issues. But as a soldier, I struggled to place these concerns in the larger context of the war. Worrying about the environment seemed disconnected from our strategy and purpose in Iraq. As I traveled to outposts and communities, witnessing Americans and Iraqis alike working to satisfy their basic needs for food, water, and sanitation, I came to realize the power of the natural environment to provide security just as readily as it could instigate conflict.

I once viewed the environment as simply an inspiring playground, but the Army showed me its potential to threaten human well-being. Iraq taught me it is something more complicated, something woven into every facet of our community, culture, and commerce. The deployment pushed my understanding of environmentalism beyond a niche interest or political position to something of a deeper, ingrained relevance.

I remember the cow in the river differently now. She was there to escape the grueling heat. I was there for water samples. Small fishing boats floated nearby while barges laden with oil sailed for the Persian Gulf. The scene was at once idyllic, threatening, and bigger than all of us.

POSTSCRIPT

I am far from alone as a veteran drawing links between the military and environmental imperatives. Carina Roselli, an Army pilot and classmate of mine, was inspired by her deployment to study law and the environmental impact of conflict, and ultimately worked with Nature Iraq to explore the water issues in Kurdish regions of northern Iraq. A soldier from my Connecticut National Guard unit, Sergeant First Class Jonathan Trouern-Trend, brought his love of birdwatching to Iraq and subsequently published a book titled Birding Babylon. Richard Kidd, former Army officer Richard Kidd, now Energy & Sustainability Deputy Assistant Secretary of the Army, works to ensure the military is leading the charge on sustainability in their operations. Veteran-led organizations are mobilizing. Operation Free is lobbying for freedom from fossil fuels. Vets Voice Foundation, led by Garrett Reppenhagen, advocates for land conservation out west. As Garrett explains, "the outdoors are a place where veterans can heal from war. We fought for these lands overseas; now we want to protect them."

Map by **JOSEPH CALAMIA**

WILDLIFE TRACKERS

THE ULTIMATE

BY KAITLIN STACK WHITNEY

Below: CK-9 Scooby braves subzero temperatures to help scientists learn more about northeast Alberta's endangered caribou population.

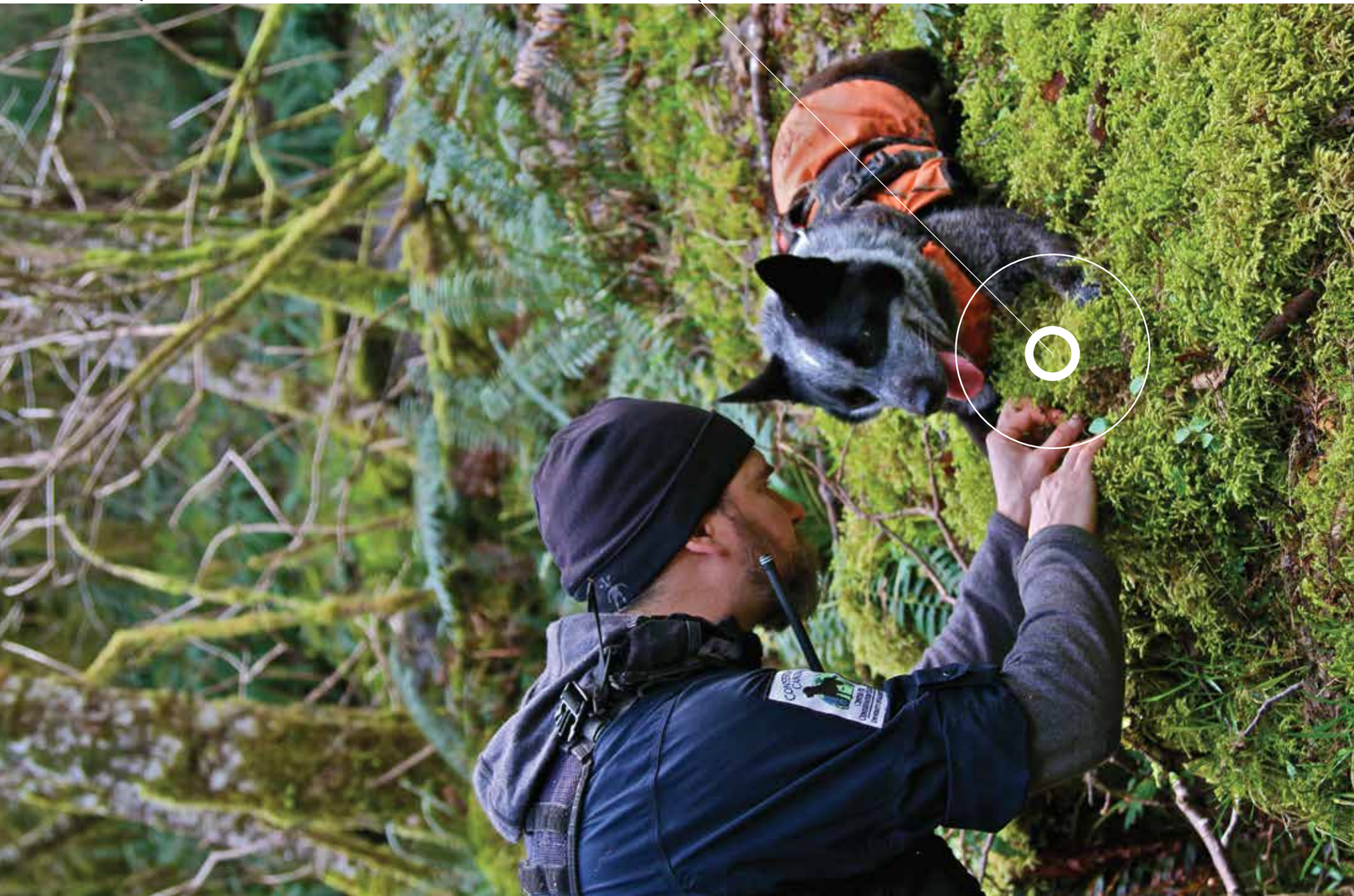
Photograph (below) by **JENNIFER HARTMAN**

Photograph (left) by **BERRY WILDEVEN**

MORE THAN SIMPLY OUR "BEST FRIEND," DOGS ARE HELPING SCIENTISTS CONSERVE ENDANGERED SPECIES AND CHANGING THE NATURE OF WILDLIFE RESEARCH

Left: handler Heath Smith and CK-9 Pips investigate traces of the endangered Haida Gwaii ermine off the coast of British Columbia.

PHOTOGRAPHS COURTESY OF CONSERVATION CANINES



PEPSI STANDS LEANING OVER THE BOW

and scans the water off the coast of Washington's San Juan Islands. She is cruising along in a small motorboat with her research team looking for orca feces, floating masses the consistency of pancake batter and stinking of rotten fish. It can be quite a challenge to spot the scat – which ranges in color from white to green and is often smaller than a handful of Hershey's kisses – against the sun's reflection on the waves of Bellingham Bay. Even more challenging, it's a race against time. If Pepsi doesn't find the scat within half an hour after it's been deposited on the surface, the feces sinks and is lost. When she does detect scat, Pepsi motions to her colleagues and directs the boat driver across the water so the team can collect their samples. But Pepsi isn't using her eyes. And she isn't a person.

Pepsi is a conservation canine. Also known as wildlife detection dogs, conservation canines are trained to sniff out threatened and endangered species or other wildlife. While Pepsi is trained to find Southern Resident killer whale scat, these dogs can be, and are, trained to track all kinds of wildlife: from orca to owls, foxes to frogs, bats to bobcats. Pepsi's work helps scientists understand the causes of orca decline in the Pacific Northwest; scat can reveal insights into their diet and the toxicants present in their bodies. Other ongoing projects with conservation canines include biologists from the Desert Research Institute tracking threatened desert tortoises in California, a team at Dalhousie University searching for ribbon snakes in Nova Scotia, and a consortium of agencies mapping rare salamander distribution in New Mexico.

YOU BEGIN TO SEE the study organism as a dog would, which opens up new insights and questions. Understanding a whale through smell is a whole new world for marine biologists.

Above: Handler Liz Seely and CK-9 Tucker track killer whales in Washington's Puget Sound. Dogs can smell orca scat from a nautical mile.

Dr. Samuel Wasser, Director of the Center for Conservation Biology at the University of Washington, pioneered the use of dogs like Pepsi for conservation biology in 1997. Collaborating with law enforcement canine handlers, he modified techniques used to train narcotic detection dogs to instead focus their noses on wildlife. There's good reason to trust dogs with this task. A human's sense of smell is isolated to a small part of the roof of the nasal cavity; but dogs have a dedicated area in the back of the nose for olfaction. It's filled with turbinates, tiny bony structures that sort odor molecules based on their chemical properties. Dogs also have a second scenting organ that humans do not: Jacobson's organ, also known as the vomeronasal organ, located in the bottom of dogs' nasal passages. This organ detects and isolates pheromones, allowing dogs to identify species-specific scent cues.

The anatomical complexity may seem underwhelming until you compare the magnitude of difference between humans and dogs. With an average of 220 million scent receptors, a dog's olfactory sense is at least 10,000 times more acute than a person's.

Perhaps counter-intuitively then, wildlife detection dogs are not selected for their strong sense of smell. Bloodhounds are thought to be the best scenting breed on the planet, with 300 million scent receptors so reliable that bloodhound-based evidence is admitted as court testimony. Yet the dogs selected to be conservation canines are often Labradors. While they have a wide range of scenting abilities, "Labs are one of the most behaviorally malleable breeds," says James Tantillo, a lecturer at Cornell University and an expert on animal ethics and the philosophy of hunting. He acknowledges that English setters and pointers have better noses, but adds, "Labs are less risky behaviorally, less likely than other breeds to fight or bite."

Photograph by **JANE COGAN**

"It's all about the game for them," says Patricia McConnell, an expert on dog behavior and professor of human-animal relationships at the University of Wisconsin-Madison. "Usually dogs are selected for loving play, not because they're obsessed with smell. Play is such a great motivator." That drive is critical for dogs like Pepsi who spend hours on the open water searching for whale scat. This kind of grueling fieldwork requires researchers, and the dogs, not to give up until the task is complete.

Pepsi and other dogs must receive extensive training before being sent into the field. Conditioning dogs to properly detect wildlife and their scat takes dedicated handlers, and a long time. First, an isolated scent is used to train the dog on the correct target. It's imperative that the scent be very specific. Cat Warren, author of What the Dog Knows: The Science and Wonder of Working Dogs and associate professor at North Carolina State University, stresses the importance of not inadvertently training them on another scent. "If it's a live tortoise you want the dog to find, make sure you are training dogs on live tortoise scent, not their shells or their poop," she says. "One scientist used swabs of the necks of live tortoises to get the dogs going on the right scent."

Above: CK-9 Gator shows off the tenacity a Conservation Canine needs to make it in the program.

The next step is to sync communication between the dog and her handler; conservation canines are only successful in tandem with their human counterparts. It doesn't matter if Pepsi can smell orca scat from a nautical mile if she can't effectively tell her handler how far and in which direction to go. Each dog is a unique individual with its own cues so much of the training focuses on the handler, not the dog. One dog might tug their leash, another might bark. In a training setting, handlers watch how the dogs react and hone in on a target scent from different distances and directions. They also pay attention to the cues dogs give when they "alert," or indicate that the target has been reached. These behaviors are the ones trainers hope to reinforce and reliably replicate in research settings.

This is where play comes in. The handler rewards the dog with her ball every time she alerts to the correct target. However, it's critical that the reward is given only when the dog discovers the right target. "Just because a dog alerts on a hole in the ground doesn't mean there's a black-footed ferret down the hole," says Warren. "If you reward the dog for finding the hole, the dog might just alert on holes." The environmental conditions must also be right for the dog to perform. If the wind is too strong or the boat isn't positioned perpendicular to the prevailing wind direction, the dog might miss its target.

On one hand, conservation canines are simply the latest development in a long history of wildlife research techniques. The earliest methods, including direct observation, stalking, and specimen collection, were largely informed by hunting. By the 19th century, biologists began affixing a visual marker to an animal, which proved helpful for tracking long-range migratory species. "Then you knew not only that a flock of Canada geese arrived at a particular pond every year; you knew that the exact same flock arrived every year," says Kristoffer Whitney, a researcher at the University of Wisconsin-Madison who specializes in the history and ethics of wildlife biology. By tracking the annual movements of specific geese flocks, for example, ornithologists identified several flight paths or "flyways" that migratory birds follow across oceans and continents. During the 20th century, wildlife agencies began using aerial surveys and radio telemetry to monitor wildlife populations. These days, researchers use satellite transmitters, geolocators, and drones to observe and monitor wildlife.

On the other, in a time when remote technologies are increasingly being employed for scientific research, conservation canines can be seen as a radical departure from this lineage. Working with wildlife detection dogs reveals different information than that of their mechanized counterparts. Distinct from the vision-based technologies like trail cameras or infrared sensors on drones, the use of scent to find hard-to-see excrement enables researchers a more unbiased sampling method. For example, without the help of the dogs, humans or their cameras might only spot the largest scat samples from a boat or the sky. Working with dogs increases the number and diversity of samples because researchers are able to include samples that would have previously gone undetected. Moreover, the use of scat as an observation indicator, rather than a picture of wildlife, gives insight into much more than population counts, including diet, physiological health, and environmental stress. But of course the biggest difference is the use of a live animal – the dog – to search out another live animal.

IT'S ALL ABOUT the game. Dogs are selected for their loving play, not because they're obsessed with smell.

And that concept is nothing new. "Dogs have been bred for thousands of years to trail," says Tantillo. "This is just the latest iteration of that," he says. McConnell puts it bluntly: "There is a reason we do this work with dogs. It's an amazing partnership in so many ways." The exceptional connection between humans and dogs is a key reason why scientists choose to work with dogs even if it is more expensive and challenging than working with inanimate tools.

Dogs and their handlers form a remarkable bond, each relying on the other to successfully complete their mission. In her book When Species Meet, science studies scholar Donna Haraway describes the relationship between dogs and their trainers as the epitome of human-animal connection, characterized by shared understanding, purpose, and concern. This can be seen in the bond between guide dogs and their owners. "A guide dog handler must literally trust their dog with their life. This is not hyperbole," says Andrew Hasley, a genetics researcher at the University of Wisconsin-Madison and owner of Fletcher, a guide dog he received from Guiding Eyes for the Blind over ten years ago. "I'm not always giving the commands. Sometimes Fletcher is telling me what to do. If a handler doesn't completely trust their dog, the relationship won't work." It's also evident with hunters and their dogs. Brandon Barton, a postdoctoral researcher at the University of Wisconsin-Madison, has been hunting with his friends' dogs for over 20 years. "The dogs are instrumental in the hunt," he says. "Houndsmen say they can tell what the bear is doing based on the sound of their dogs – Is it running? Is it treed? Is it fighting back? They can tell!" Tantillo concurs. He calls his hunting dogs "friends for life." "Sometimes I'm hunting for the dog, not even for myself," he says. "It's a unique relationship."

There is a distinctive element, however, to the partnership between the conservation canine, its handler, and the scientists with whom they work. "We would expect scientists to have a close relationship with the dog in the service of their scientific study based on what we know about dogs as companions," says Whitney. "But this adds another layer of complexity to the study as well." His research has shown that scientists have an emotional connection to their study organisms, and that this concern affects how science is carried out; it forces scientists to reflect on and consider the perspective and welfare of the animal in their research design. The use of dogs likewise changes how scientists design their studies in order to learn about their study animals while keeping the dogs safe. As Makie Matsumoto-Hervol, a research intern working on the same boat as Pepsi this past summer puts it, "The dogs become your coworkers. Each one has a distinct personality and preferences that you have to work with. There is this almost natural inclination to shower them with carrots or pet them every time you see them." Whitney says that while this complicates the study design, it also makes for richer research. "A lot of studies of animals require you to take on the perspective of the animal you're studying in order to understand its behavior. So if you start using a dog as a research companion, you're going to begin seeing the study organism as a dog would, which could open up new insights and questions. Understanding a whale through smell is a whole new world for marine biologists."

Both dogs and drones can be considered as a continuum of technologies that scientists are employing to study and help conserve threatened species. Yet wildlife detection dogs are true partners in science, qualitatively and quantitatively changing the research process. This has led a small but growing number of conservation researchers to spend the extra time, energy, and money to train the conservation canines, the handlers and the research team to work together. With dogs guiding scientists literally and metaphorically into new waters, they are emerging as collaborators in the future of conservation.

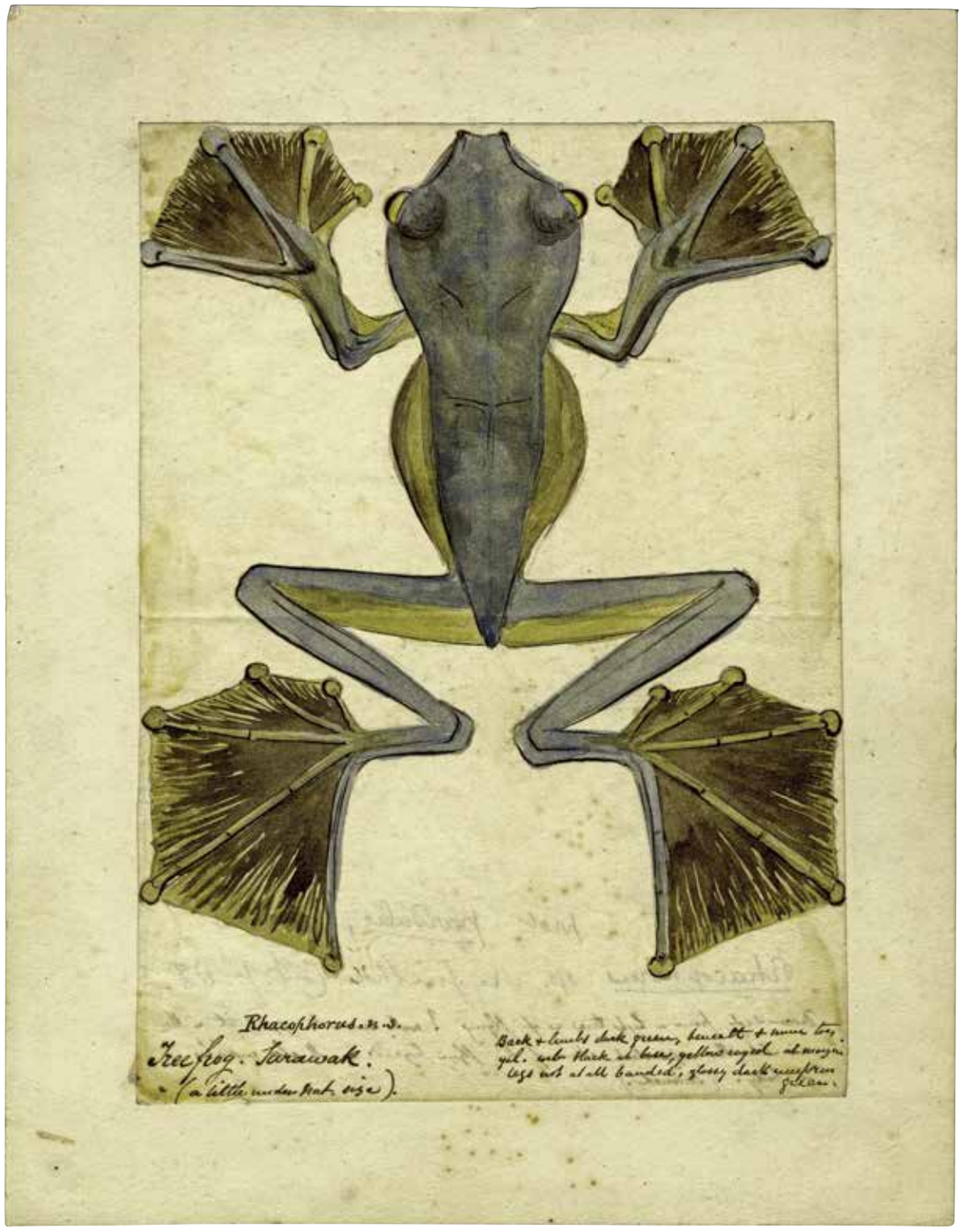
PHOTOGRAPH BY CENTER FOR CONSERVATION BIOLOGY/HEATH SMITH

ILLUSTRATION BY LISA NOMURA

WALLACE'S Line

What the Galapagos were for Darwin, Wallacea was for Alfred Russel Wallace: a living laboratory

BY JESSE LEWIS



Wallace's Flying Frog (Rhacophorus nigropalmatus) by Wallace, 1855.
Images scanned with permission from the Wallace family.

Aeschynanthus flower by Wallace, 1855.

Illustrations courtesy of **A. R. WALLACE MEMORIAL FUND**

BIRDWING BUTTERFLIES DANCE

in the sulfurous steam rising from the summit of Gunung Api, an active volcano in Indonesia's Spice Islands. Beneath its rocky cone, the volcano's steep slopes are cloaked in a dense, tropical forest. Lizards scurry in the leaf litter and fruit doves murmur in the afternoon shadows. Under the forest canopy, spice gardens fringe sandy beaches that give way to coral gardens full of octopuses, sea turtles, and reef fishes.

This is the "other Galapagos," a living laboratory of evolution called Wallacea. Named for the British naturalist and explorer Alfred Russel Wallace, this biologically rich archipelago serves as a transition zone between the Indo-Maylayan and Australian worlds. Stretching from Bali and Borneo in the west to New Guinea in the east, Wallacea encompasses Sulawesi, a large, spider-shaped island; the Moluccas, or Spice Islands; and the Lesser Sundas, including Timor Leste. Famous as a biodiversity hotspot, Wallacea is home to an astonishing array of endemic species. Some 265 birds, 125 mammals, and 100 reptiles – including the world's largest, the Komodo dragon – are found nowhere else on Earth.

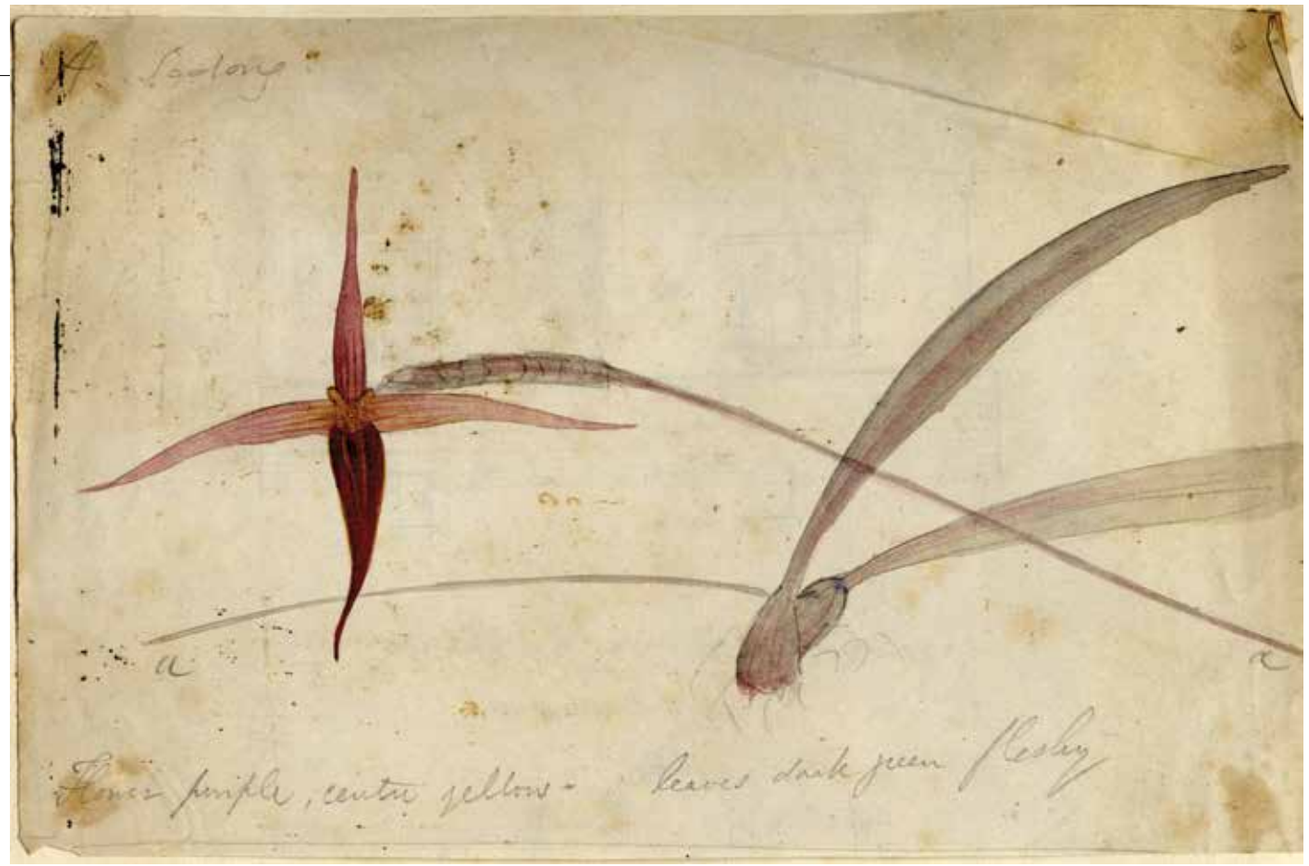
Between 1854 and 1862, Wallace voyaged 14,000 miles throughout Indonesia, exploring every major island in the Malay Archipelago. Through careful observation, Wallace discovered an invisible species boundary that distinguished the faunas of Asia from those of Australia. Today that boundary is known as Wallace's Line. Animals living on the Asian side, like tigers, look very different than those living on the Australian side, like marsupial kangaroos. Describing this boundary in 1859, Wallace wrote, "In this Archipelago there are two distinct faunas rigidly circumscribed, which differ as much as those of South America and Africa, and more than those of Europe or North America: yet there is nothing on the map or on the face of the islands to mark their limits." Scientists now know that Wallace's Line corresponds with a deep-water trench that acted as a barrier to animal migrations when sea levels were much lower during previous ice ages. The trench separated islands from one another and shaped distinct biogeographic regions on each side of the line.

Wallace collected over 100,000 specimens of insects, shells, bird skins, reptiles, and mammals on his expeditions. When he netted a new birdwing butterfly, Wallace wrote, "The beauty and brilliancy of this insect are indescribable, and none but a naturalist can understand the intense excitement I experienced when I at length captured it. On taking it out of my net and opening the glorious wings, my heart began to beat violently, the blood rushed to my head, and I felt much more like fainting than I have done when in apprehension of immediate death."

In particular, Wallace found Sulawesi to be "a strange and remarkable land." The creatures were more similar to those in Asia and while "poor in actual number of species, wonderfully rich in peculiar forms." Wallace observed endemic species such as the pig-like babirusa and the maleo, a chicken-sized bird that incubates its eggs in huge mounds of warm sand. Based in south Sulawesi in 1856, Wallace wrote, "I have rarely enjoyed myself more than during my residence here. As I sat taking coffee at six in the morning, rare birds would often be seen on some tree close by, when I would hastily sally out in my slippers, and perhaps secure a prize I had been seeking after for weeks. The great hornbills of Sulawesi (Buceros cassidix) would often come with loud-flapping wings, and perch upon a lofty tree just in front of me; and the black baboon monkeys (Cynopithecus nigrescens) often stared down in astonishment at such an intrusion into their domain."

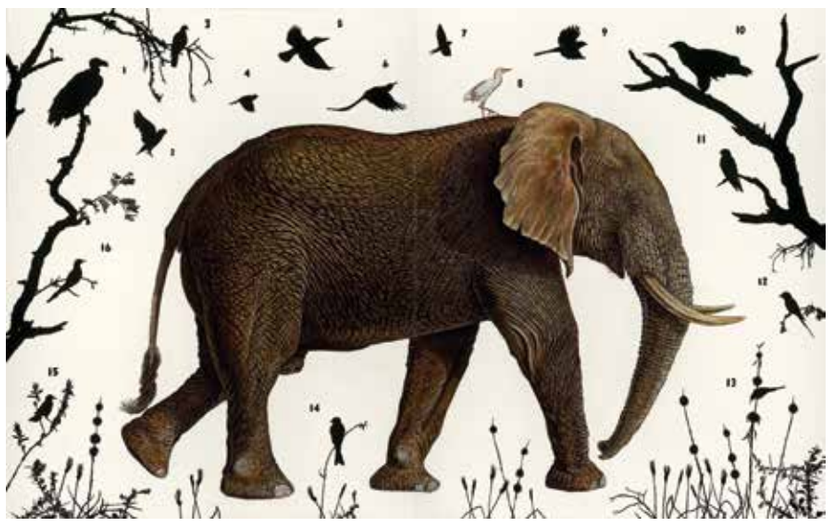
Such eclectic species were instrumental to Wallace's understanding of this boundary and contributed to his theories of evolution and biogeography. In 1858, while bedridden with malaria on the remote island of Halmahera in North Maluku, Wallace wrote a letter to his friend, Charles Darwin. His letter described how evolution proceeds through natural selection. Darwin had arrived at the same conclusion and hastened to publish his seminal work, On the Origin of Species. And while both men are credited with the theory of evolution by natural selection, Wallace's contributions are far less remembered.

Today, Wallace would likely be disheartened by the extent to which agriculture, commercial logging, and oil palm plantations have transformed the islands of Wallacea. Though humans have inhabited these islands for 40,000 years, most habitat destruction has taken place during the last century. Over 80 of Wallacea's vertebrate species are now threatened with extinction. And yet, there are still places where one can catch a glimpse of the world Wallace knew. In Lore Lindu National Park in central Sulawesi, tiny tarsiers haunt the primordial forests and red-knobbed hornbills swoop through the canopy. Purple bearded bee-eaters and dwarf kingfishers streak through the forest understory while Sulawesi hawk-eagles hover over the valleys. The wild setting resembles much of what Wallace described in the 19th century.



Clockwise from above: Watercolor of an orchid by Wallace; photo of an original Carte de viste by Thomas Sims in the NHM's Wallace Archive; female rhinoceros hornbill by Wallace, circa 1855.

Photograph (top right) courtesy of **THE NATURAL HISTORY MUSEUM, LONDON**



CREATING UNNATURAL HISTORY

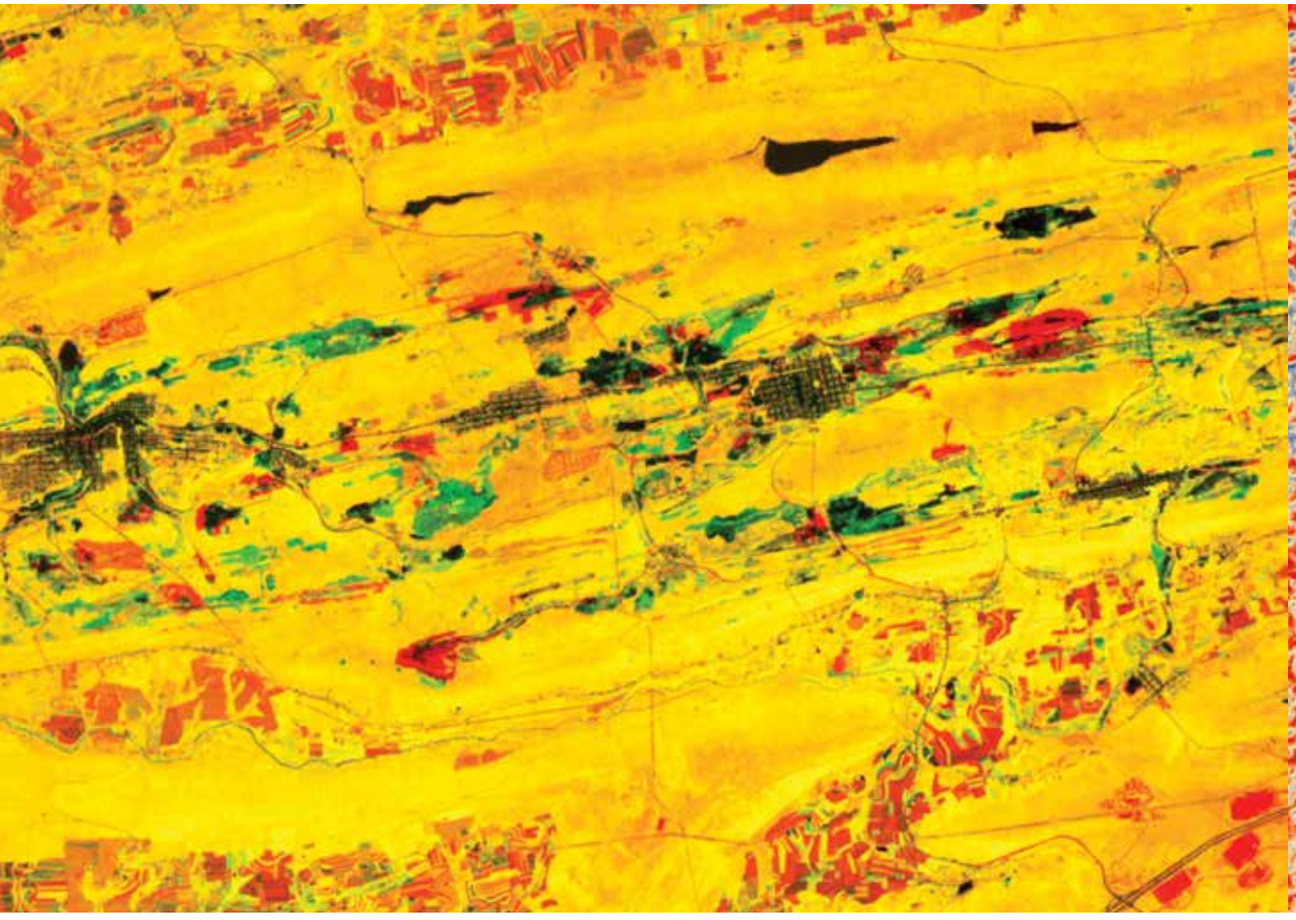
A Connecticut artist weaves together worlds both real and imagined in his work.

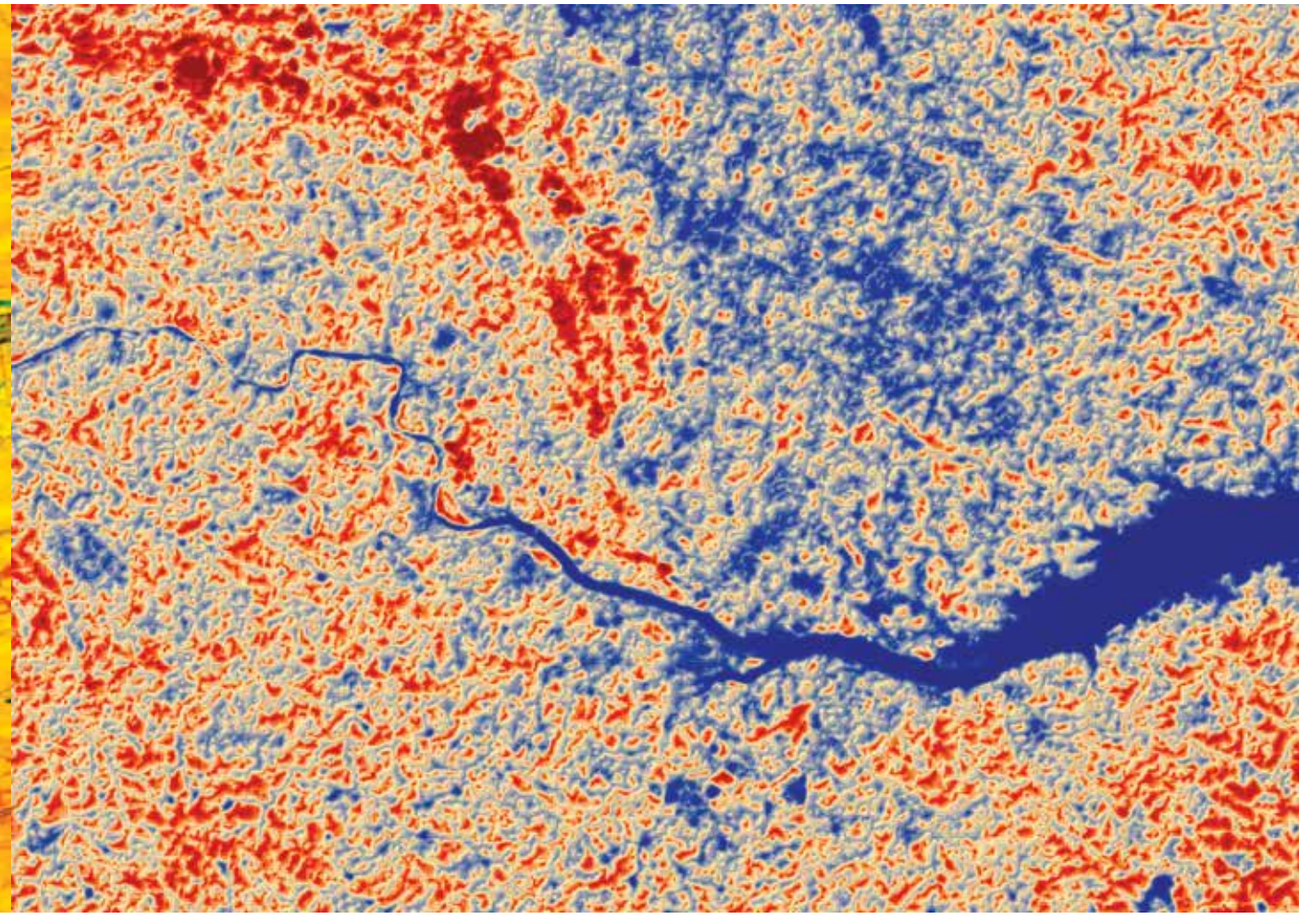
By JAMES PROSEK

MY WORK questions accepted notions of how we understand and interpret the natural world. Examining the ways in which we name and order nature, the systems we use to try to harness nature, our classifications and taxonomies, and the limitations of language in describing biological diversity, I invite viewers to reflect on what these systems say about our culture, our priorities, and our values. As a contemporary artist I address our environmental concerns in a world where we are losing natural diversity faster than we can discover it. Yet I also mine the changing relationship that modern humans have had with nature in the relatively brief time since we walked out of Africa and spread across the globe. My current projects include a book about how and why we name and order the natural world.

Illustrations by **JAMES PROSEK**

The interval between USGS Landsat satellite passes **16 days**





BURN MARKS

Satellites measure underground fires from 700 km above Earth's surface

By JOSEPH CALAMIA

EARTH-OBSERVING SATELLITES allow us to see environmental change in ways human eyes cannot. These two images, both created using information captured during USGS Landsat satellite missions, provide different ways of seeing underground coal mine fires.

In 1962, a fire started in an abandoned coal mine in Centralia, Pennsylvania. In 1984, after repeated attempts—and failures—to extinguish the underground blaze, the United States Congress spent $42 million dollars to relocate the town's residents. This image is a composite of two satellite images, one from 1984 and another from 2014, showing vegetation change over Columbia County, Pennsylvania. Red areas indicate places of vegetation decrease; green areas show vegetation increase; and yellow areas indicate little change in vegetation cover during this thirty-year period. To the far right of the image's center, a small grid of green shows vegetation growth over the streets of the abandoned town.

A much older and larger coalmine fire continues to burn at the Jharia Coalfield, about 240 kilometers northwest of Kolkata, India. In 1916, spontaneous combustion and poor mining practices reportedly started the coalfield burning, and the mine has continued to burn since. The image above, from January 2014, uses satellite-recorded thermal infrared radiation to determine temperature. Areas corresponding to lowest temperatures appear in blue, and warmest areas appear in dark red. In blue, the Panchet Reservoir and Damodar River are clearly visible. On upper left, Jharia coal mine fires appear in deep red.

Above left: Image created using Normalized Difference Vegetation Index from Landsat 4 TM and Landsat 8 OLI, USGS.

Above: Image created using Landsat 8 TIRS, USGS.

Images by **JOSEPH CALAMIA**

SAGE

EXPANDING ENVIRONMENTALISM THROUGH
PROVOCATIVE CONVERSATION AND THE ARTS.