NATIONAL GEOGRAPHIC

FEBRUARY 2015

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HEALING OUR SOLDIERS

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FEBRUARY 2015
VOL. 227 • NO. 2

In the town of Khairpur Nathan Shah, Pakistan, a man stands in water from the 2010 floods that left about one-fifth of the country inundated.

PHOTO: GIDEON MENDEL

On the Cover Marine Gunnery Sgt. Aaron Tam (Ret.) holds the mask he made in an art therapy class for service members and veterans with traumatic brain injuries and psychological conditions. *Photograph by Lynn Johnson* | **Corrections and Clarifications** Go to *ngm.com/more.*

FROM THE EDITOR

Healing Our Soldiers

The Art of Recovery

Air Force Staff Sgt. Robert "Bo" Wester (Ret.) was an explosive ordnance disposal technician in Iraq. He faced hundreds of IEDs without incident and a few with grievous consequences. "Most of my injuries are invisible, and the rest are hidden," he says. Army Maj. Jeff Hall (Ret.) was 35 feet from a car bomb when it went off in a crowded marketplace north of the city of Baghdad. He didn't lose his arms or his legs or suffer visible wounds. But "I am just not the same human being as I used to be," he says.

A longtime Army flight medic, Perry Hopman suffered blast-force injuries while caring for other soldiers.

PHOTO: LYNN JOHNSON

Brain injuries caused by the shock waves generated by explosions have become the signature injury of the Afghanistan and Iraq wars, leaving hundreds of thousands of U.S. soldiers and veterans with a life-altering list of debilitating conditions, including headaches, seizures, sleep disorders, and memory and cognitive difficulties. The range of symptoms and their similarity to PTSD can complicate diagnosis and treatment. It's a mystery that has dogged soldiers and scientists since World War I, when exploding artillery shells left men "shell shocked."

Even today "there is no consensus within the medical community about the nature of blast-induced injury or by what mechanism blast force damages the brain," Caroline Alexander writes in this issue. "As of now, the only wholly reliable method of directly examining the biological effects of blast force on the human brain is autopsy."

Which doesn't do much for vets like Wester and Hall, who struggle daily. If there isn't a cure, at least there are ways to cope. At Walter Reed Medical Center in Bethesda, Maryland, soldiers at the National Intrepid Center of Excellence paint masks that help them reveal their inner feelings. Some were initially dismissive: "Number one, I'm a man, and I don't like holding a dainty little paintbrush. Number two, I'm not an artist. And number three, I'm not in kindergarten," said Army Staff Sgt. Perry Hopman. Today he says, "I was wrong... I think this is what started me kind of opening up and talking about stuff and actually trying to get better."

Major Hall agrees. He painted a gruesome, bloodstained mask—part of the skull missing, brain exposed. "I had seen a person who looked like this," he explains. "I don't know why, but that's what needed to come out of me."

The artwork, he says, is a silent testimony to pain that speaks volumes yet has the capacity to heal. "You can't put it into words that people will believe, or if you do put it into words, they get tired of it. But the art just expresses itself. It relieves the soldier, because you get tired of trying to explain what is going on in there. The artwork is like a printed page—it is there if you want to read it."

We invite you to read our soldiers' masks and the stories they tell.

Susan Goldberg, *Editor in Chief*

Hog Deer *(Axis porcinus)*
Size: Head and body length, 120 - 127 cm (47.3 - 50 inches); shoulder height, 66 - 74 cm (26 - 29 inches) **Weight:** 32 - 50 kg (80 - 110 lbs) **Habitat:** Generally associated with tall grasslands in riparian areas or near coasts **Surviving number:** Unknown; populations declining

Photographed by Anup Shah

WILDLIFE AS CANON SEES IT

Eater and eaten. A prodigious consumer of grass, the hog deer also enjoys snacking on fruit, such as the luscious plums of the Indian Jujube. Typically foraging during the day, it switches to nighttime when the weather is hot or in areas where it is often hunted. And the short, squat deer does find itself a frequent target; it is a favored prey of tigers and leopards, and is also pursued by humans for the bush-meat trade. Even its habitat is being eaten up due to cultivation, making the task of everyday survival more and more difficult all the time.

As Canon sees it, images have the power to raise awareness of the threats facing endangered species and the natural environment, helping us make the world a better place.


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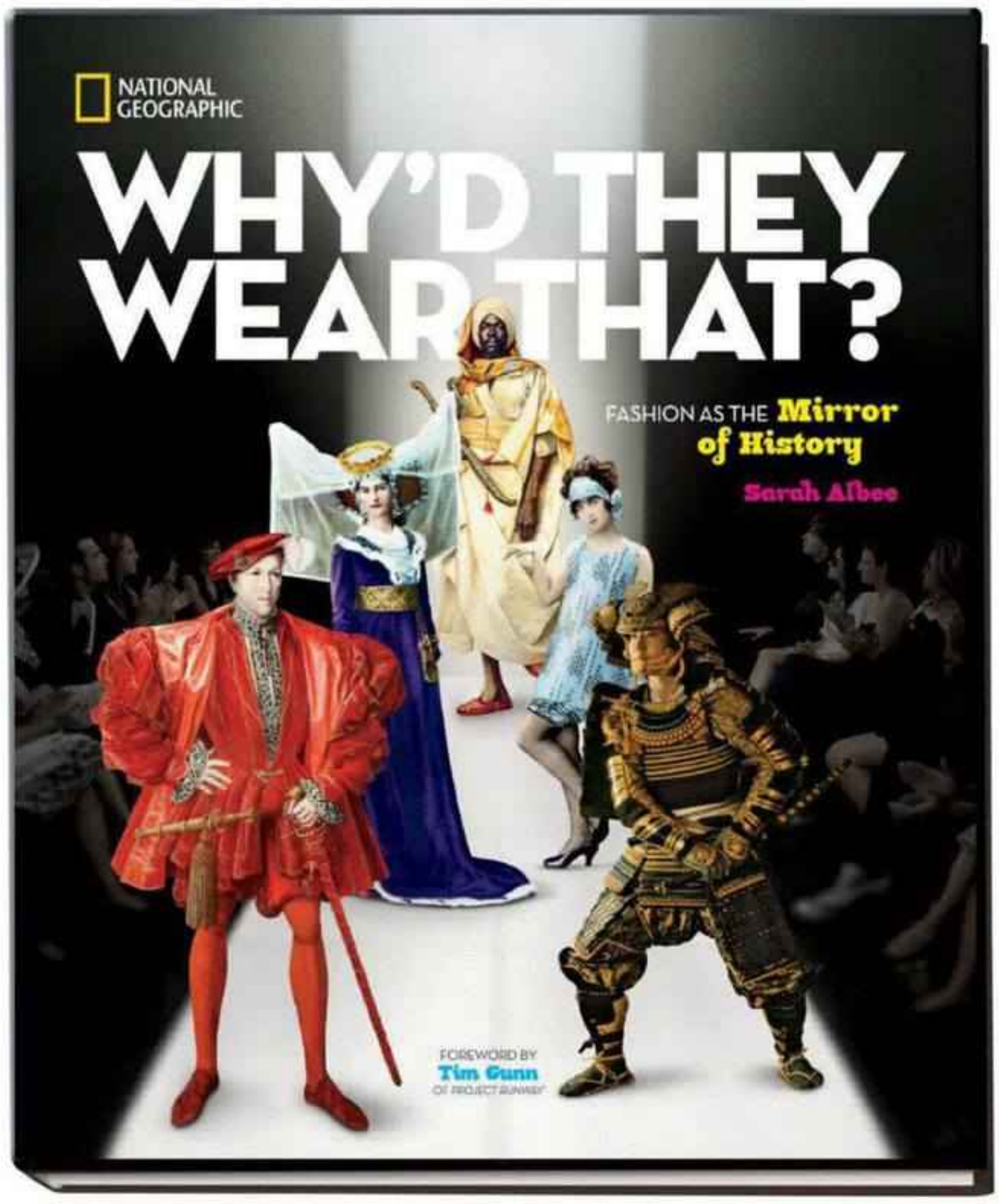
GOT A PASSION FOR **Fashion** AND A HUNGER FOR **History?**



Hoop skirts and hair shirts, togas and T-shirts … read the history of the world through the engaging lens of fashion. *Why'd They Wear That?* looks at what people wore through the ages to reveal the social, cultural, and economic fabric of the day.

By Sarah Albee
with a foreword by
Project Runway's *Tim Gunn*

Why did ancient **warriors** wear fishnet **stockings?**

How did the **automobile** drive **fashion?**

What started the **corset craze?**

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3 Questions
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Why I Care About the New Wild

M. Sanjayan is a conservation biologist and an executive vice president of Conservation International. He's also host of the National Geographic–produced television series *EARTH: A New Wild,* premiering February 4 on PBS. Sanjayan traveled to 15 countries over five years to shoot the five-part documentary.

WHAT DO YOU MEAN BY YOUR SHOW'S TITLE, *A NEW WILD*?
The new wild is the realization that we humans are part of nature and that saving nature is really about saving ourselves. Nature isn't something out there, far away. It's living, breathing. It's part of us.

WHY IS THIS NEW WILD SO IMPORTANT?
I love nature. I live in Montana; I grew up in Africa. Wild places are almost places of worship for me. But love alone isn't enough to save them. And in some cases, as we show in the program, when nature is taken off track, the consequences for human life are epic. I don't think people quite get that. If we did, we wouldn't make the decisions we do.

SO IS THERE ANYTHING THAT GIVES YOU HOPE?
In this show we discover stories where there is a way out. We show you, front line, when giant pandas—one of the rarest animals on the planet in one of the most crowded places on the planet—go back into the wild. You see how communities in Bangladesh still manage to tolerate tigers—animals that kill their family members. In Austin, Texas, the whole city celebrates bats. In New York Harbor oysters are coming back to life in the shadow of skyscrapers. I'm left with a sense of optimism that when you understand nature, you absolutely can harness that power to make both nature and our lives better.

Episodes of *EARTH: A New Wild* will air at 9 p.m. and 10 p.m. ET, February 4, and 10 p.m. ET on February 11, 18, and 25 on PBS.

PHOTO: REBECCA HALE, NGM STAFF

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EXPLORE

Wild Things

Vine on the Run

In its own destructive way, kudzu is impressive. A relative of the pea, the vine was introduced to the United States from Japan in 1876 to create quick shade and stabilize soil. But its growth is so fast—up to a foot a day—and undiscerning that it carpets trees, light posts, and even buildings. Across at least 20 states, thousands of square miles of field and forest have disappeared under it.

New research suggests kudzu may be doing still more damage. Scientists at Clemson University report it may accelerate climate change by decreasing carbon stored in the soil of the native-plant ecosystems it overruns (such as the Mississippi woodland seen here). The carbon loss happens mostly in topsoil and occurs over decades, says weed ecologist Nishanth Tharayil. Previous studies have shown that kudzu may also release other greenhouse gases.

The question that matters most: Can the vine be stopped? While herbicide makers try to catch up to the speedy pest, gardeners can always kill it the old-fashioned way, by digging up the plant's roots. *—Daniel Stone*

PHOTO: ANDY ANDERSON

Last Call for Pubs?

Like the French café, the British pub is more than a watering hole. It's what regulars call a home away from home—and a social institution that can anchor a community.

But for how much longer? U.K. pub numbers, dwindling for decades, are now in free fall. Since 2008 about 7,000 have shuttered or been sold off to developers—and each week 31 more close, says Neil Walker of the consumer group Campaign for Real Ale.

Changing tastes, economics, and laws, along with supermarkets selling cheap beer and more restaurants serving alcohol, have all spurred the decline, says pub advocate John Longden. The result, he says, is "fewer pubs but more places to drink."

Most U.K. "locals," as they're known, used to belong to breweries, says author and historian Paul Jennings. Then a 1989 antimonopoly law gave pub companies control. Some say these "pubcos" make changes that trample tradition; others argue that they foster needed diversity by changing the pub landscape.

Could variety pour life back into pubs? "If pubs don't mirror the social and economic changes of their community," says Longden, "they're dead." *—Jeremy Berlin*

The number of traditional British pubs (like the circa 1967 London "local" above) is declining. But drinkers, take note: An average of 33 new drinking establishments a week opened in the U.K. in 2014, according to the food and drink consulting firm CGA Strategy.

Pub Abundance in Great Britain

Number of pubs

PHOTO: DAVID HURN, MAGNUM PHOTOS. GRAPHIC: EMILY M. ENG, NGM STAFF
SOURCE: BRITISH BEER AND PUB ASSOCIATION

For patients 12 years and older whose asthma is not well controlled on a long-term asthma medicine or whose disease severity warrants

IF YOU THINK ASTHMA "COMES AND GOES"

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Inflammation, the root cause of asthma, is always there, making you more vulnerable to triggers. So, while it's important to avoid triggers, it's also important to treat this inflammation. SYMBICORT helps reduce that underlying inflammation, which can mean improved lung function, and better breathing all day and night, when taken twice daily. Once your asthma is well controlled with SYMBICORT, your doctor may switch you to a long-term asthma control medicine such as an inhaled corticosteroid.

IMPORTANT INFORMATION ABOUT SYMBICORT

Important Safety Information About SYMBICORT

SYMBICORT contains formoterol, a long-acting beta$_2$-adrenergic agonist (LABA). LABA medicines such as formoterol increase the risk of death from asthma problems. It is not known whether budesonide, the other medicine in SYMBICORT, reduces the risk of death from asthma problems seen with formoterol.

- **Call your health care provider if breathing problems worsen over time while using SYMBICORT. You may need different treatment**
- **Get emergency medical care if:**
  - o Breathing problems worsen quickly, and
  - o You use your rescue inhaler medicine, but it does not relieve your breathing problems

SYMBICORT should be used only if your health care provider decides that your asthma is not well controlled with a long-term asthma control medicine, such as an inhaled corticosteroid, or that your asthma is severe enough to begin treatment with SYMBICORT.

If you are taking SYMBICORT, see your health care provider if your asthma does not improve or gets worse. It is important that your health care provider assess your asthma control on a regular basis. Your doctor will decide if it is possible for you to stop taking SYMBICORT and start taking a long-term asthma control medicine without loss of asthma control.

Children and adolescents who take LABA medicines may have an increased risk of being hospitalized for asthma problems.

SYMBICORT does not replace rescue inhalers for sudden symptoms. Be sure to tell your health care provider about all your health conditions, including heart conditions or high blood pressure, and all medicines you may be taking. Some patients taking SYMBICORT may experience increased blood pressure, heart rate, or change in heart rhythm.

Do not use SYMBICORT more often than prescribed. While taking SYMBICORT, never use another medicine containing a LABA for any reason. Ask your health care provider or pharmacist if any of your other medicines are LABA medicines.

SYMBICORT can cause serious side effects, including:

- **Pneumonia and other lower respiratory tract infections.** People with COPD may have a higher chance of pneumonia. Call your doctor if you notice any of the following symptoms: change in amount or color of mucus, fever, chills, increased cough, or increased breathing problems
- **Serious allergic reactions** including rash, hives, swelling of the face, mouth and tongue, and breathing problems
- **Immune system effect and a higher chance of infection.** Tell your health care provider if you think you are exposed to infections such as chicken pox or measles, or if you have any signs of infection such as fever, pain, body aches, chills, feeling tired, nausea, or vomiting
- **Adrenal insufficiency.** This can happen when you stop taking oral corticosteroid medicines and start inhaled corticosteroid medicine
- **Using too much of a LABA medicine** may cause chest pain, increase in blood pressure, fast and irregular heartbeat, headache, tremor, or nervousness
- **Increased wheezing** right after taking SYMBICORT. Always have a rescue inhaler with you to treat sudden wheezing
- **Eye problems including glaucoma and cataracts.** You should have regular eye exams while using SYMBICORT
- **Lower bone mineral density** can happen in people who have a high chance for low bone mineral density (osteoporosis)
- **Slowed growth in children.** A child's growth should be checked regularly while using SYMBICORT
- **Swelling of blood vessels** (signs include a feeling of pins and needles or numbness of arms or legs, flu like symptoms, rash, pain or swelling of the sinuses), decrease in blood potassium and increase in blood sugar levels

Common side effects in **patients with asthma** include nose and throat irritation, headache, upper respiratory tract infection, sore throat, sinusitis, stomach discomfort, flu, back pain, nasal congestion, vomiting, and thrush in the mouth and throat.

Approved Uses for SYMBICORT

SYMBICORT 80/4.5 and 160/4.5 are medicines for the treatment of asthma for people 12 years and older whose doctor has determined that their asthma is not well controlled with a long-term asthma control medicine such as an inhaled corticosteroid or whose asthma is severe enough to begin treatment with SYMBICORT. SYMBICORT is not a treatment for sudden asthma symptoms.

Please see Important Product Information on adjacent page and discuss with your doctor.

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IMPORTANT INFORMATION ABOUT SYMBICORT

Please read this summary carefully and then ask your doctor about SYMBICORT.

No advertisement can provide all the information needed to determine if a drug is right for you or take the place of careful discussions with your health care provider. Only your health care provider has the training to weigh the risks and benefits of a prescription drug.

WHAT IS THE MOST IMPORTANT INFORMATION I SHOULD KNOW ABOUT SYMBICORT?

People with asthma who take long-acting $beta_2$-agonist (LABA) medicines, such as formoterol (one of the medicines in SYMBICORT), have an increased risk of death from asthma problems. It is not known whether budesonide, the other medicine in SYMBICORT, reduces the risk of death from asthma problems seen with formoterol.

SYMBICORT should be used only if your health care provider decides that your asthma is not well controlled with a long-term asthma control medicine, such as an inhaled corticosteroid, or that your asthma is severe enough to begin treatment with SYMBICORT. Talk with your health care provider about this risk and the benefits of treating your asthma with SYMBICORT.

If you are taking SYMBICORT, see your health care provider if your asthma does not improve or gets worse. It is important that your health care provider assess your asthma control on a regular basis. Your doctor will decide if it is possible for you to stop taking SYMBICORT and start taking a long-term asthma control medicine without loss of asthma control.

Get emergency medical care if:

- breathing problems worsen quickly, and
- you use your rescue inhaler medicine, but it does not relieve your breathing problems.

Children and adolescents who take LABA medicines may be at increased risk of being hospitalized for asthma problems.

WHAT IS SYMBICORT?

SYMBICORT is an inhaled prescription medicine used for asthma and chronic obstructive pulmonary disease (COPD). It contains two medicines:

- Budesonide (the same medicine found in Pulmicort Flexhaler™, an inhaled corticosteroid). Inhaled corticosteroids help to decrease inflammation in the lungs. Inflammation in the lungs can lead to asthma symptoms
- Formoterol (the same medicine found in Foradil® Aerolizer®). LABA medicines are used in patients with COPD and asthma to help the muscles in the airways of your lungs stay relaxed to prevent asthma symptoms, such as wheezing and shortness of breath. These symptoms can happen when the muscles in the airways tighten. This makes it hard to breathe, which, in severe cases, can cause breathing to stop completely if not treated right away

SYMBICORT is used for asthma and chronic obstructive pulmonary disease as follows:

Asthma

SYMBICORT is used to control symptoms of asthma and prevent symptoms such as wheezing in adults and children ages 12 and older.

Chronic Obstructive Pulmonary Disease

COPD is a chronic lung disease that includes chronic bronchitis, emphysema, or both. SYMBICORT 160/4.5 mcg is used long term, two times each day, to help improve lung function for better breathing in adults with COPD.

WHO SHOULD NOT USE SYMBICORT?

Do not use SYMBICORT to treat sudden severe symptoms of asthma or COPD or if you are allergic to any of the ingredients in SYMBICORT.

WHAT SHOULD I TELL MY HEALTH CARE PROVIDER BEFORE USING SYMBICORT?

Tell your health care provider about all of your health conditions, including if you:

- **have heart problems**
- **have high blood pressure**
- **have seizures**
- **have thyroid problems**
- **have diabetes**
- **have liver problems**
- **have osteoporosis**
- **have an immune system problem**
- **have eye problems such as increased pressure in the eye, glaucoma, or cataracts**
- **are allergic to any medicines**
- **are exposed to chicken pox or measles**
- **are pregnant or planning to become pregnant.** It is not known if SYMBICORT may harm your unborn baby
- **are breast-feeding.** Budesonide, one of the active ingredients in SYMBICORT, passes into breast milk. You and your health care provider should decide if you will take SYMBICORT while breast-feeding

Tell your health care provider about all the medicines you take including prescription and nonprescription medicines, vitamins, and herbal supplements. SYMBICORT and certain other medicines may interact with each other and can cause serious side effects. Know all the medicines you take. Keep a list and show it to your health care provider and pharmacist each time you get a new medicine.

HOW DO I USE SYMBICORT?

Do not use SYMBICORT unless your health care provider has taught you and you understand everything. Ask your health care provider or pharmacist if you have any questions.

Use SYMBICORT exactly as prescribed. **Do not use SYMBICORT more often than prescribed.** SYMBICORT comes in two strengths for asthma: 80/4.5 mcg and 160/4.5 mcg. Your health care provider will prescribe the strength that is best for you. SYMBICORT 160/4.5 mcg is the approved dosage for COPD.

- SYMBICORT should be taken every day as 2 puffs in the morning and 2 puffs in the evening.
- Rinse your mouth with water and spit the water out after each dose (2 puffs) of SYMBICORT. This will help lessen the chance of getting a fungus infection (thrush) in the mouth and throat.
- Do not spray SYMBICORT in your eyes. If you accidentally get SYMBICORT in your eyes, rinse your eyes with water. If redness or irritation persists, call your health care provider.
- Do not change or stop any medicines used to control or treat your breathing problems. Your health care provider will change your medicines as needed
- **While you are using SYMBICORT 2 times each day, do not use other medicines that contain a long-acting $beta_2$-agonist (LABA) for any reason. Ask your health care provider or pharmacist if any of your other medicines are LABA medicines.**
- SYMBICORT does not relieve sudden symptoms. Always have a rescue inhaler medicine with you to treat sudden symptoms. If you do not have a rescue inhaler, call your health care provider to have one prescribed for you.

Call your health care provider or get medical care right away if:

- your breathing problems worsen with SYMBICORT
- you need to use your rescue inhaler medicine more often than usual
- your rescue inhaler does not work as well for you at relieving symptoms
- you need to use 4 or more inhalations of your rescue inhaler medicine for 2 or more days in a row
- you use one whole canister of your rescue inhaler medicine in 8 weeks' time
- your peak flow meter results decrease. Your health care provider will tell you the numbers that are right for you
- your symptoms do not improve after using SYMBICORT regularly for 1 week

WHAT MEDICATIONS SHOULD I NOT TAKE WHEN USING SYMBICORT?

While you are using SYMBICORT, do not use other medicines that contain a long-acting $beta_2$-agonist (LABA) for any reason, such as:

- Serevent® Diskus® (salmeterol xinafoate inhalation powder)
- Advair Diskus® or Advair® HFA (fluticasone propionate and salmeterol)
- Formoterol-containing products such as Foradil Aerolizer, Brovana®, or Perforomist®

WHAT ARE THE POSSIBLE SIDE EFFECTS WITH SYMBICORT?

SYMBICORT can cause serious side effects.

- Increased risk of pneumonia and other lower respiratory tract infections if you have COPD. Call your health care provider if you notice any of these symptoms: increase in mucus production, change in mucus color, fever, chills, increased cough, increased breathing problems
- Serious allergic reactions including rash; hives; swelling of the face, mouth and tongue; and breathing problems. Call your health care provider or get emergency care if you get any of these symptoms
- Immune system effects and a higher chance for infections
- Adrenal insufficiency–a condition in which the adrenal glands do not make enough steroid hormones
- Cardiovascular and central nervous system effects of LABAs, such as chest pain, increased blood pressure, fast or irregular heartbeat, tremor, or nervousness
- Increased wheezing right after taking SYMBICORT
- Eye problems, including glaucoma and cataracts. You should have regular eye exams while using SYMBICORT
- Osteoporosis. People at risk for increased bone loss may have a greater risk with SYMBICORT
- Slowed growth in children. As a result, growth should be carefully monitored
- Swelling of your blood vessels. This can happen in people with asthma
- Decreases in blood potassium levels and increases in blood sugar levels

WHAT ARE COMMON SIDE EFFECTS OF SYMBICORT?

Patients with Asthma

Sore throat, headache, upper respiratory tract infection, thrush in the mouth and throat

Patients with COPD

Thrush in the mouth and throat

These are not all the side effects with SYMBICORT. Ask your health care provider or pharmacist for more information.

NOTE: This summary provides important information about SYMBICORT. For more information, please ask your doctor or health care provider.

Manufactured for: AstraZeneca LP, Wilmington, DE 19850
By: AstraZeneca AB, Dunkerque, France Product of France
Rev 11/11 1504903

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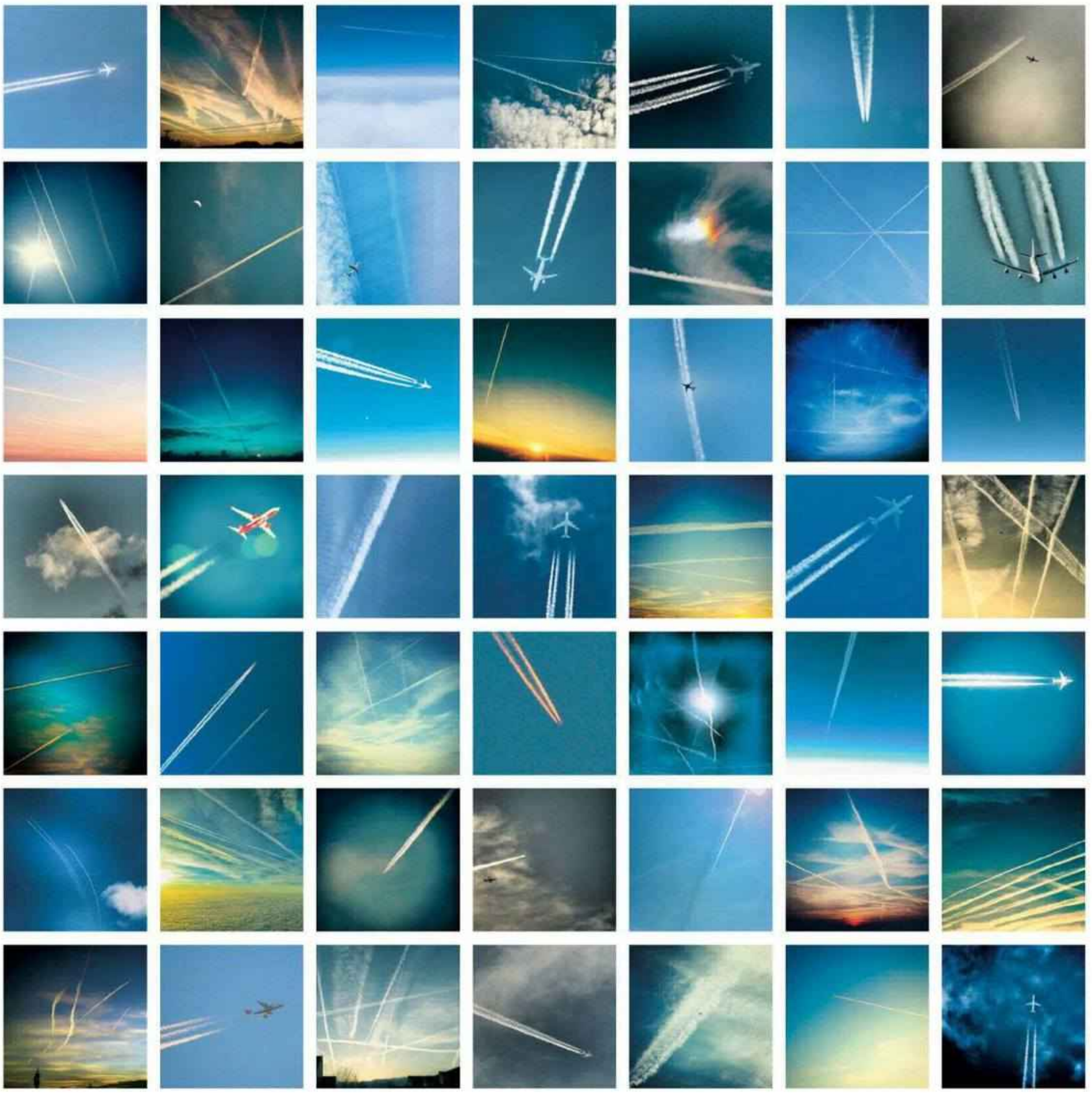

Climate Change and Contrails

When water vapor in hot aircraft exhaust hits very cold, moist air, it freezes. That creates white contrails, which can spread into wispy cirrus clouds with climate change potential. Some reflect the sun's heat before it reaches Earth's surface, for a cooling effect. But overall, contrail cirrus clouds trap heat and, by one estimate, contribute more to warming than aircraft carbon dioxide emissions do.

Planes could be rerouted to avoid contrail-inducing weather, a study in *Environmental Research Letters* found. In one case, a 13.7-mile detour in a transatlantic flight eliminated a contrail 62 miles long and the clouds it would have spurred—so even counting extra emissions from the detour, the flight resulted in less warming. Nonetheless, no one suggests rerouting planes yet. Forecasters can predict contrail formation, says study author Emma Irvine—but whether the forecasts are accurate enough to justify flight adjustments is still up in the air. *—Alison Fromme*

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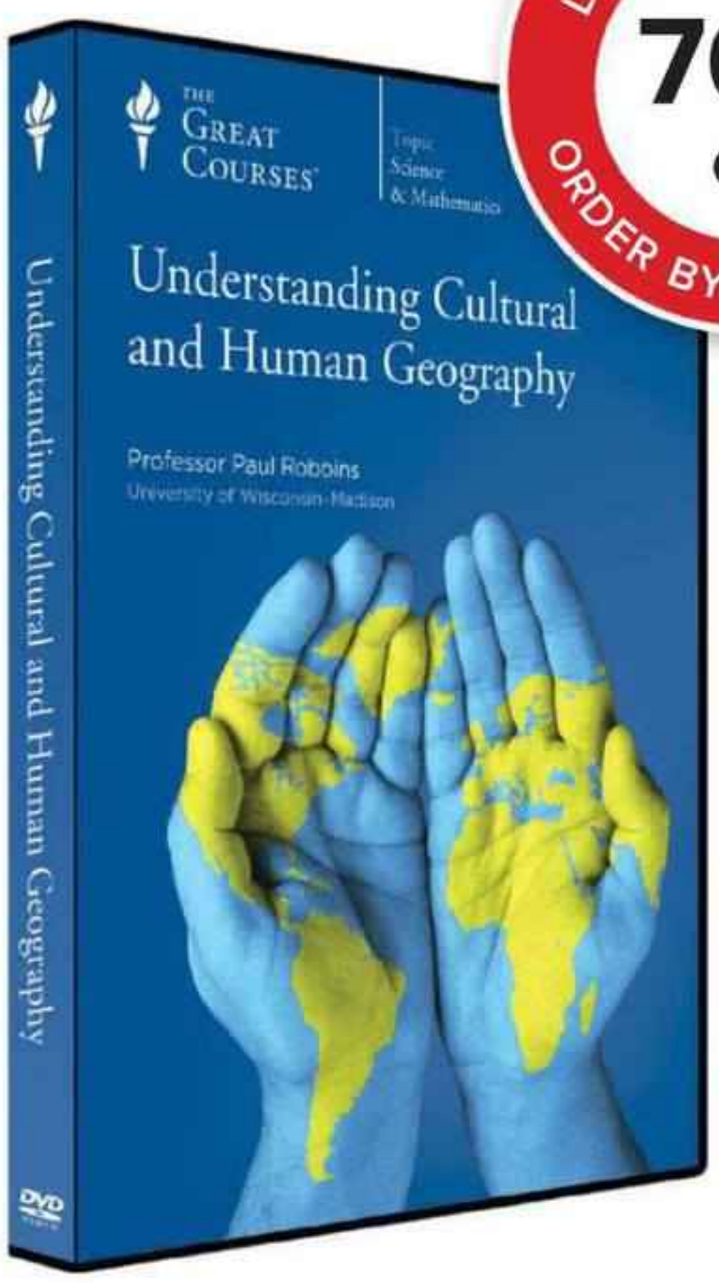

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Fleeing Disaster

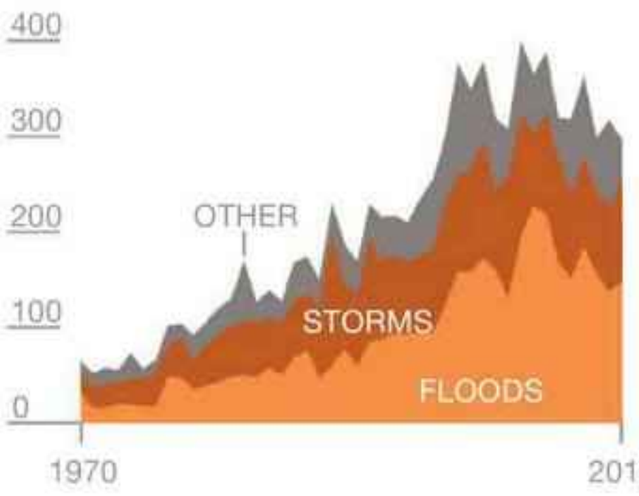
Torrential rains, typhoons, and floods force millions from their homes every year. Those who live in poverty are the most likely to be displaced. In the past 40 years the urban population of developing countries has grown more than 320 percent, putting even more people in potential paths of destruction.

Climate change is expected to make extreme weather worse and more frequent. Political conflicts and natural disasters such as earthquakes are compounding issues. Says Michelle Yonetani of the Internal Displacement Monitoring Centre, "We are increasingly talking about crisis in the plural." —*Kelsey Nowakowski*

A GLOBAL LOOK

CLIMATE DISASTERS*

The number of events has risen, in part due to population growth and better reporting.



DISPLACED PEOPLE

21 million

PEOPLE WERE FORCED FROM THEIR HOMES BY CLIMATE-RELATED DISASTERS IN 2013.

CLIMATE-RELATED DISASTERS IN 2013

Weather-related events such as floods and storms accounted for 94 percent of all disaster displacements, geophysical events such as earthquakes, 6 percent.

69% METEOROLOGICAL Storms

30% HYDROLOGICAL Mostly floods

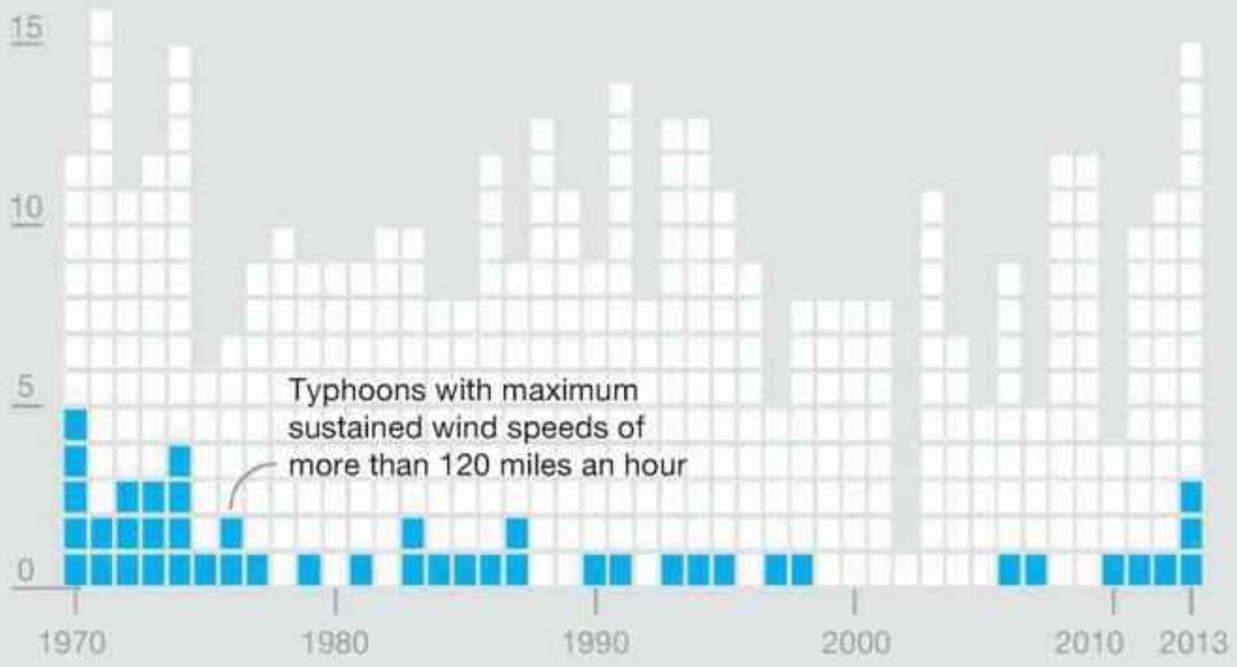
1% CLIMATOLOGICAL Mostly wildfires

*Includes events that met one or more of these criteria: 10 deaths, 100 people affected, declaration of state of emergency, call for international assistance

TYPHOON HAIYAN, PHILIPPINES

In November 2013 Haiyan, the largest typhoon to make landfall ever recorded, hit the Philippines, killing 6,200 people. With more than 7,000 islands and located on the Pacific Ring of Fire, the country is vulnerable to natural hazards.

NUMBER OF TROPICAL STORMS AND TYPHOONS IN THE PHILIPPINES



POPULATION

Since 1970, the Philippines has been on track to triple its population by 2020. More than half its people live in flood-prone areas.

15%
OF FILIPINOS LIVE IN LOW-ELEVATION COASTAL ZONES (LESS THAN 33 FEET ABOVE SEA LEVEL)

PATH OF DESTRUCTION

In the areas affected by Typhoon Haiyan, 24 percent of the homes were made of bamboo. Only 16 percent were made of stone or concrete.

WHERE WILL THEY GO?

A year after the typhoon, thousands of displaced people were still uncertain about where they would live.

DECEMBER 2013

4.1 million

NOVEMBER 2014

0.9 m

PEOPLE DIDN'T KNOW IF THEIR HOMES COULD BE MADE SAFE TO LIVE IN AGAIN.

MOST AFFECTED

Averages, 2008-2013

60% OF THE WORLD'S PEOPLE LIVE IN ASIA...

BUT THEY ACCOUNT FOR **80%** OF THE WORLD'S DISPLACED PEOPLE.

TOP 5 WEATHER EVENTS THAT DISPLACED THE MOST PEOPLE IN 2013

All of the top 16 events were in Asia.

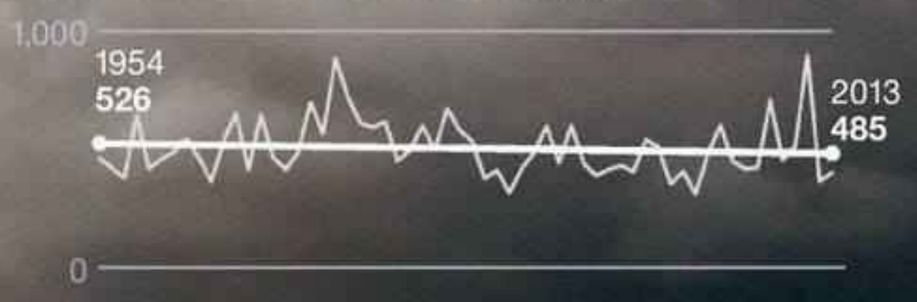
GRAPHIC: ÁLVARO VALIÑO. MAP: JEROME N. COOKSON, NGM STAFF. SOURCES: INTERNATIONAL BEST TRACK ARCHIVE FOR CLIMATE STEWARDSHIP; UN OFFICE FOR THE COORDINATION OF HUMANITARIAN AFFAIRS; PHILIPPINES DEPARTMENT OF SOCIAL WELFARE AND DEVELOPMENT; INTERNAL DISPLACEMENT MONITORING CENTRE; WORLD BANK; INTERNATIONAL DISASTER DATABASE; JOINT TYPHOON WARNING CENTER; CIESIN, COLUMBIA UNIVERSITY

Spin Cycle

Over the past six decades the number of days when at least one tornado touched down in the United States has dropped. When climatologist James Elsner saw the data on that decline, he found it strange. "We know that the atmosphere is getting warmer and more humid," he says, "so we might expect to see some fingerprint of climate change in tornado activity."

Then Elsner and his Florida State University colleagues found a fingerprint: On days when there are tornadoes, there are likely to be a lot more of them. Outbreaks of 32 or more twisters in a single day were once rare in the U.S.; since 2001 they've become a yearly occurrence. "If the atmosphere is becoming more efficient at producing tornadoes," Elsner cautions, more people will need to pay attention when storms are forecast. *—Rachel Hartigan Shea*

Number of Tornadoes
Tornadoes in the United States each year



Number of Tornado Days
Days with at least one tornado in the U.S.

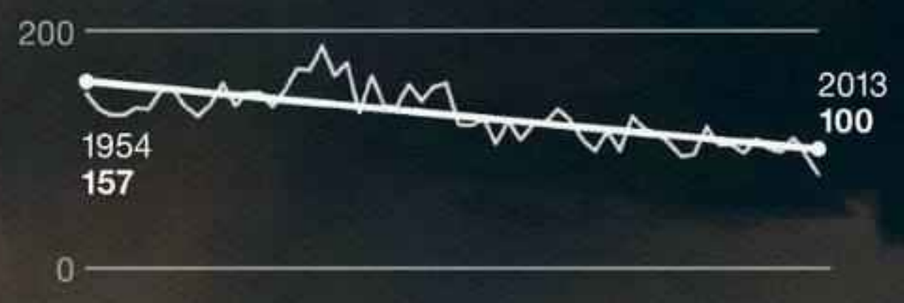


PHOTO: JIM REED. NGM ART. SOURCES: JAMES ELSNER, SVETOSLAVA ELSNER, AND THOMAS JAGGER, FLORIDA STATE UNIVERSITY; NOAA STORM PREDICTION CENTER

Diabetic Nerve Pain (or pain from Diabetic Peripheral Neuropathy) is characterized by shooting, burning, pins and needles symptoms. **In some patients, LYRICA has been clinically proven to provide effective pain relief.*** Some patients also had a significant reduction of pain in as early as one week. And, LYRICA is not a narcotic.†

Ask your doctor about LYRICA today.

*Individual results may vary. †Those who have had a drug or alcohol problem may be more likely to misuse LYRICA. We asked Daniel to tell us about his experience with LYRICA. To hear Daniel's story visit LYRICA.com.

Prescription LYRICA is not for everyone. Tell your doctor right away about any serious allergic reaction that causes swelling of the face, mouth, lips, gums, tongue, throat, or neck or any trouble breathing, rash, hives or blisters. LYRICA may cause suicidal thoughts or actions in a very small number of people. Patients, family members or caregivers should call the doctor right away if they notice suicidal thoughts or actions, thoughts of self harm, or any unusual changes in mood or behavior. These changes may include new or worsening depression, anxiety, restlessness, trouble sleeping, panic attacks, anger, irritability, agitation, aggression, dangerous impulses or violence, or extreme increases in activity or talking. If you have suicidal thoughts or actions, do not stop LYRICA without first talking to your doctor. LYRICA may cause swelling of your hands, legs and feet. Some of the most common side effects of LYRICA are dizziness and sleepiness. Do not drive or work with machines until you know how LYRICA affects you. Other common side effects are blurry vision, weight gain, trouble concentrating, dry mouth, and feeling "high." Also, tell your doctor right away about muscle pain along with feeling sick and feverish, or any changes in your eyesight including blurry vision or any skin sores if you have diabetes. You may have a higher chance of swelling, hives or gaining weight if you are also taking certain diabetes or high blood pressure medicines. Do not drink alcohol while taking LYRICA. You may have more dizziness and sleepiness if you take LYRICA with alcohol, narcotic pain medicines, or medicines for anxiety. If you have had a drug or alcohol problem, you may be more likely to misuse LYRICA. Tell your doctor if you are planning to father a child. Talk with your doctor before you stop taking LYRICA or any other prescription medication.

Please see Important Risk Information for LYRICA on the following page.

To learn more visit www.LYRICA.com or call toll-free 1-888-9-LYRICA (1-888-959-7422).

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.FDA.gov/medwatch or call 1-800-FDA-1088.

IMPORTANT FACTS

LYRICA® PREGABALIN © capsules

(**LEER**-i-kah)

IMPORTANT SAFETY INFORMATION ABOUT LYRICA

LYRICA may cause serious, even life threatening, allergic reactions.
Stop taking LYRICA and call your doctor right away if you have any signs of a serious allergic reaction:
- Swelling of your face, mouth, lips, gums, tongue, throat or neck
- Have any trouble breathing
- Rash, hives (raised bumps) or blisters

Like other antiepileptic drugs, LYRICA may cause suicidal thoughts or actions in a very small number of people, about 1 in 500.
Call your doctor right away if you have any symptoms, especially if they are new, worse or worry you, including:
- suicidal thoughts or actions
- new or worse depression
- new or worse anxiety
- feeling agitated or restless
- panic attacks
- trouble sleeping
- new or worse irritability
- acting aggressive, being angry, or violent
- acting on dangerous impulses
- an extreme increase in activity and talking
- other unusual changes in behavior or mood

If you have suicidal thoughts or actions, do not stop LYRICA without first talking to your doctor.

LYRICA may cause swelling of your hands, legs and feet.
This swelling can be a serious problem with people with heart problems.

LYRICA may cause dizziness or sleepiness.
Do not drive a car, work with machines, or do other dangerous things until you know how LYRICA affects you. Ask your doctor when it is okay to do these things.

ABOUT LYRICA

LYRICA is a prescription medicine used in adults 18 years and older to treat:
- Pain from damaged nerves that happens with diabetes or that follows healing of shingles, or spinal cord injury
- Partial seizures when taken together with other seizure medicines
- Fibromyalgia (pain all over your body)

Who should NOT take LYRICA:
- Anyone who is allergic to anything in LYRICA

BEFORE STARTING LYRICA

Tell your doctor about all your medical conditions, including if you:
- Have had depression, mood problems or suicidal thoughts or behavior
- Have or had kidney problems or dialysis
- Have heart problems, including heart failure
- Have a bleeding problem or a low blood platelet count
- Have abused prescription medicines, street drugs or alcohol in the past
- Have ever had swelling of your face, mouth, tongue, lips, gums, neck, or throat (angioedema)
- Plan to father a child. It is not known if problems seen in animal studies can happen in humans.
- Are pregnant, plan to become pregnant or are breastfeeding. It is not known if LYRICA will harm your unborn baby. You and your doctor should decide whether you should take LYRICA or breast-feed, but you should not do both.

Tell your doctor about all your medicines. Include over-the-counter medicines, vitamins, and herbal supplements. LYRICA and other medicines may affect each other causing side effects. Especially tell your doctor if you take:

BEFORE STARTING LYRICA, continued

- Angiotensin converting enzyme (ACE) inhibitors. You may have a higher chance for swelling and hives.
- Avandia® (rosiglitazone)*, Avandamet® (rosiglitazone and metformin)* or Actos® (pioglitazone)** for diabetes. You may have a higher chance of weight gain or swelling of your hands or feet.
- Narcotic pain medicines (such as oxycodone), tranquilizers or medicines for anxiety (such as lorazepam). You may have a higher chance for dizziness and sleepiness.
- Any medicines that make you sleepy.

POSSIBLE SIDE EFFECTS OF LYRICA

LYRICA may cause serious side effects, including:
- See "Important Safety Information About LYRICA."
- Muscle problems, pain, soreness or weakness along with feeling sick and fever
- Eyesight problems including blurry vision
- Weight gain. Weight gain may affect control of diabetes and can be serious for people with heart problems.
- Feeling "high"

If you have any of these symptoms, tell your doctor right away.

The most common side effects of LYRICA are:
- Dizziness
- Blurry vision
- Weight gain
- Sleepiness
- Trouble concentrating
- Swelling of hands and feet
- Dry mouth

If you have diabetes, you should pay extra attention to your skin while taking LYRICA.

HOW TO TAKE LYRICA

Do:
- Take LYRICA exactly as your doctor tells you. Your doctor will tell you how much to take and when to take it. Take LYRICA at the same times each day.
- Take LYRICA with or without food.

Don't:
- Drive a car or use machines if you feel dizzy or sleepy while taking LYRICA.
- Drink alcohol or use other medicines that make you sleepy while taking LYRICA.
- Change the dose or stop LYRICA suddenly.
  If you stop taking LYRICA suddenly, you may have headaches, nausea, diarrhea, trouble sleeping, increased sweating, or you may feel anxious. If you have epilepsy, you may have seizures more often.
- Start any new medicines without first talking to your doctor.

NEED MORE INFORMATION?

- Ask your doctor or pharmacist. This is only a brief summary of important information.
- Go to **www.lyrica.com** or call **1-866-459-7422 (1-866-4LYRICA).**

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Version September 2014

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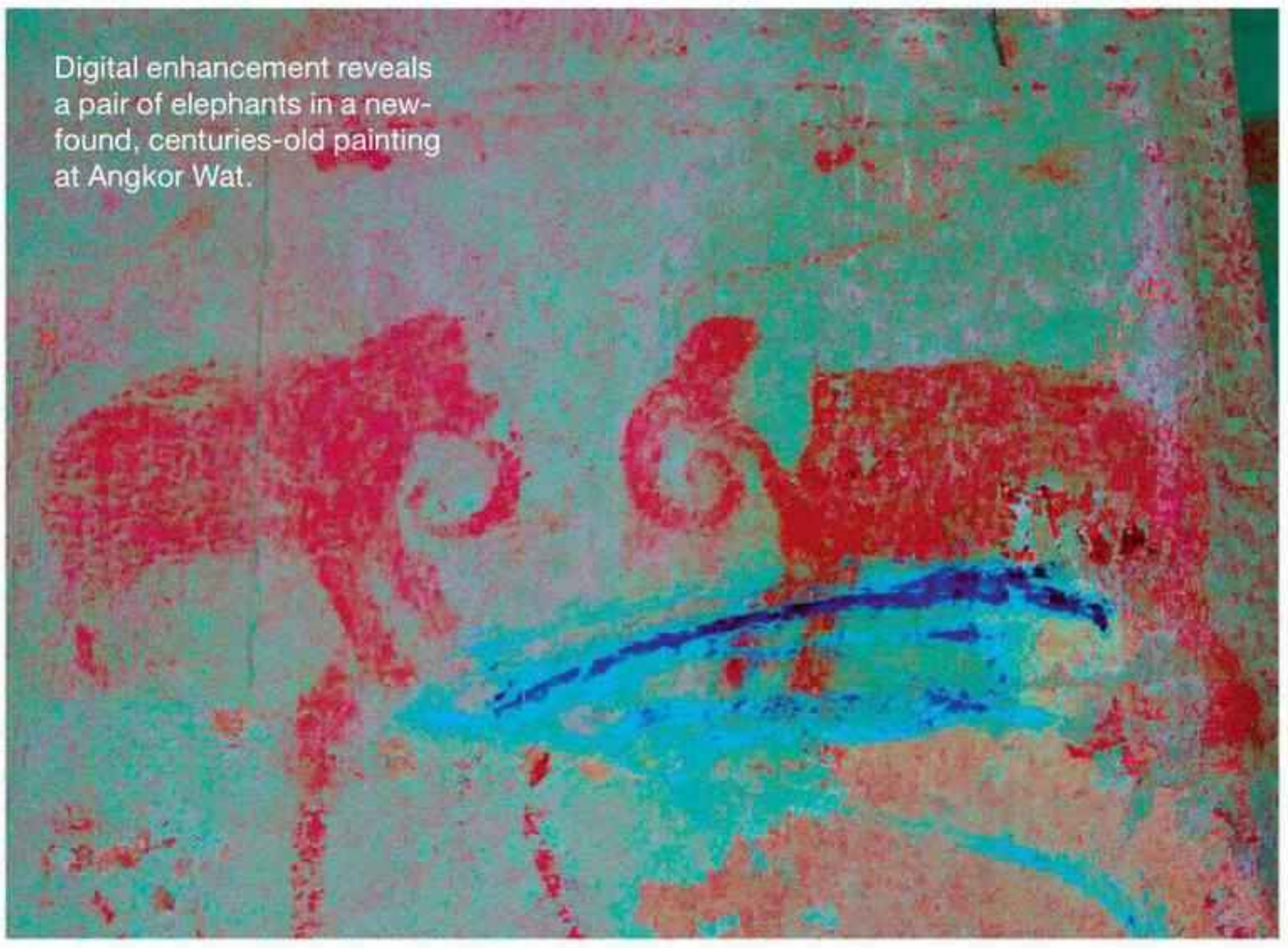

Digital enhancement reveals a pair of elephants in a new-found, centuries-old painting at Angkor Wat.

In Angkor Wat, Art Revealed

Built nine centuries ago in what is now Cambodia, Angkor Wat draws millions of visitors each year. Some head to the Buddhist temple—which was originally dedicated to the Hindu god Vishnu—for religious reasons. Others come to take in the site's famously intricate carvings. A team of archaeologists, though, is focused on a less obvious attraction: some 200 elaborate, roughly 16th-century paintings that had been obscured by the effects of weather and time.

To see them, rock art researcher and study leader Noel Hidalgo Tan uses a technique that combines digital photography and computer analysis. "What was once thought to be a faint splotch on the wall," he says, "turns out to be two elephants or an entire Khmer orchestra." The purpose of the artwork isn't clear, but further investigation could offer clues to the monument's past. Tan theorizes that some pieces were commissioned by a king.

—Catherine Zuckerman

VIKING GENDER BENDER?

At first glance a gilded silver figurine from Denmark appears to be a woman wearing a long dress. Standing 1.85 inches tall and pierced for stringing, the figurine would have hung from the neck of someone important, possibly a priest, in the ninth century. Claus Feveile, curator at the Østfyns Museums, studied the pendant after its discovery last April. He believes it may represent a Norse deity—a goddess, or perhaps even a god in the guise of a woman. "The way the figure is standing, with the hands in front of the belly, we know from a few other figurines," he says. "They are naked, and clearly men." *—A. R. Williams*

PHOTOS: NOEL HIDALGO TAN (ABOVE, BOTH); ØSTFYNS MUSEUMS

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It took three years of development and $26 million in advanced Swiss-built watch-making machinery to create the *Magnificat II*. Look at the interior dials and azure-colored hands. Turn the watch over and examine the 27-jeweled automatic movement through the exhibition back. When we took the watch to George Thomas (the most renowned watchmaker and watch historian in America), he disassembled the ***Magnificat II*** and studied the escapement, balance wheel and the rotor. He remarked on the detailed guilloche face, gilt winding crown, and the crocodile-embossed leather band. He was intrigued by the three interior dials for day, date, and 24-hour moon phases. He estimated that this fine timepiece would cost over $2,500. We all smiled and told him that the Stauer price was less than $90. He was stunned. We felt like we had accomplished our task. A truly magnificent watch at a truly magnificent price!

Try the ***Magnificat II*** for 60 days and if you are not receiving compliments, please return the watch for a full refund of the purchase price. The precision-built movement carries a 2 year warranty against defect. If you trust your own good taste, the ***Magnificat II*** is built for you.

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You Can't Hurry Love

How slow are sloths, generally considered Earth's slowest mammal? Distance moved in a day: often just a few yards. Time at rest: up to 20 hours out of each 24. Metabolism: so slow that the tree-dwelling herbivores climb down to defecate only about once a week. That's for the best, because their ungainliness on the ground makes them vulnerable to cars, humans, and other animals.

The sloth skeleton is suited for reclining or hanging upside down in trees. That's how sloths eat, sleep, give birth—and mate. Though the rain forest exhibit at Baltimore's National Aquarium has welcomed four sloth babies, the staff has never seen a sloth birth or copulation, says curator Ken Howell: "I think of them as having private lives." When seclusion does lead to sex, he says, "apparently it's very quick."

Well, yes and no, says Mark Rosenthal of Animal Magic, an exotic-animal rescue program in Michigan. With a smartphone and lucky timing, Rosenthal was able to capture "a very rare video of two of our sloths actually breeding" while hanging suspended from a branch in their habitat. His halting narration describes the protracted scene: "The male keeps trying... the girl... is receptive... He's going to try again... Those of you watching, bear with me—they're sloths..."

Because his audience includes children, Rosenthal edited the video to finish before the sloths did. The eventual consummation, he says, "was upside down. And it didn't take very long." *—Patricia Edmonds*

HABITAT
Central and South America

STATUS
Least concern (four species)

OTHER FACTS
Two of the six sloth species are at risk: Brazil's maned three-toed is vulnerable, and Panama's pygmy three-toed is critically endangered.

When one of Earth's slowest mammals mates, "apparently it's very quick."

This Linné's two-toed sloth *(Choloepus didactylus)* was photographed at the Lincoln Children's Zoo in Nebraska.

PHOTO: JOEL SARTORE


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VISIONS

NATIONAL GEOGRAPHIC • FEBRUARY 2015

Estonia
In the village of Kurtna, a pony named Rainbow basks in the winter sun. The four-year-old gelding is part Estonian native horse, part Shetland pony—two breeds known for their hardiness and versatility.

PHOTO: KERSTI KALBERG

United States
Seen from above, a seamless sheet of white paper—folded into the shape of an eye—holds and beholds 81 dancers from the New York City Ballet. This 6,500-square-foot composite image was a collaboration with the French artist JR.

PHOTO (PANORAMA COMPOSED OF MULTIPLE IMAGES): JR

United States
In a lab at the University of Alaska Fairbanks, hibernating arctic ground squirrels pose medical mysteries. The species can lower its body temperature below freezing and avoid serious head injuries while in hibernation, which lasts seven months.

PHOTO: JOEL SARTORE

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Editor's Choice

Daily Dozen Editors pick 12 photos from those submitted online each day. Here are our favorites this month.

EDITOR'S NOTE

"Photographs can be made stronger by what isn't seen. Absence—of a person or the photographer herself—invites us to look deeper and discover imaginative new layers."

—Jessie Wender, senior photo editor

Adela Zatovičová
Bzince pod Javorinou, Slovakia

A wall covered in ivy offered Zatovičová an idea for an interpretive shot of a person drowning in the leaves. With no one else around, she set up a tripod and posed.

Matyas Sarvady
Budapest, Hungary

Sarvady, who spent part of his childhood with his grandparents, tried to chronicle their 52-year marriage. After his grandfather passed away in 2014, Sarvady devised a way, using old clothes, to portray his grandfather's absence.

THE INVISIBLE WAR ON THE BRAIN

Brain trauma from blast force is the signature injury of the Iraq and Afghanistan campaigns, afflicting hundreds of thousands of U.S. combat personnel. Although unseen, the damage strikes deeply into a soldier's mind and psyche.

Marine Cpl.
Chris McNair (Ret.)
Afghanistan 2011-12

Impeccable in his Marine uniform and outwardly composed, McNair sits on the porch of his parents' home in Virginia, anonymous behind a mask he made in an art therapy session. "I was just going through pictures, and I saw the mask of Hannibal Lecter, and I thought, 'That's who I am'… He's probably dangerous, and that's who I felt I was. I had this muzzle on with all these wounds, and I couldn't tell anyone about them. I couldn't express my feelings."

Improvised explosive devices (IEDs) account for about 60 percent of all combat injuries sustained in the campaigns in Iraq and Afghanistan. Many such wounds are immediately apparent. Marine Cpl. Burness Britt is medevaced for treatment following an IED strike in June 2011 in southern Afghanistan.

ANJA NIEDRINGHAUS, AP IMAGES

Blast injury to the brain changes soldiers in ways many can't articulate; some use art therapy to reveal themselves. This mask has a slash across the face, displaying miniature cogs to evoke the military's machinelike nature. Body armor can stop shrapnel, but nothing can stop blast waves.

By Caroline Alexander
Photographs by Lynn Johnson

Inside the protective bunker I waited with the explosives team, fingers wedged firmly in my ears. Outside, shot number 52, trailing a 20-foot length of yellow-and-green-striped detonating cord, was securely taped to the wall of a one-room plywood building with a steel fire door. There was a countdown from five, a low "pow," and a dull thump in the center of my chest. The thump is the hallmark of blast. "You feel the thump," one team member told me. "I've been in blast events where we're actually hundreds or even thousands of feet away, and I still feel that thump."

The mystery of what that thump does had brought me to a World War II bombing range some 40 miles southeast of Denver. Back then it was used to test half-ton ordnance; now it serves to study controlled explosives used by soldiers to blast holes through walls and doors in combat areas—standard practice in modern warfare. The eventual objective of these tests is to discover what that blast thump does to the human brain.

According to the U.S. Department of Defense, between 2001 and 2014 some 230,000 soldiers and veterans were identified as suffering from so-called mild traumatic brain injury (TBI), mostly as a result of exposure to blast events. The variety of symptoms associated with the condition—headache, seizures, motor disorders, sleep disorders, dizziness, visual disturbances, ringing in the ears, mood changes, and cognitive, memory, and speech difficulties—the fact that they resemble symptoms of post-traumatic stress disorder (PTSD), and the fact that exposure to blast events often was not logged in the early years of the campaigns in Afghanistan and Iraq make it impossible to pin down casualty figures.

Despite the prevalence of the condition, the most fundamental questions about it remain unanswered. Not only is there no secure means of diagnosis, but there are also no known ways to prevent it and no cure. Above all, there is no consensus within the medical community about the nature of blast-induced injury or by what mechanism blast force damages the brain.

BOOM: In the field a single blast event represents a virtually simultaneous amalgam of distinct components, each uniquely damaging. Ignition sparks a chemical reaction, an instantaneous expansion of gases that pushes out a spherical wall of gas and air faster than the speed of sound. This shock wave envelops any object it encounters in a balloon of static pressure. During this fleeting stage—the primary blast effect—the individual does not move. An abrupt fall in pressure follows, creating a vacuum. Then comes the secondary blast effect, a rush of supersonic wind that floods the vacuum, hurling and fragmenting objects it encounters, weaponizing debris as high-speed, penetrating projectiles. The wind itself causes the tertiary blast effects, lifting human beings or even 15-ton armored vehicles in the air, slamming them against walls, rocks, dusty roadsides. The quaternary blast effects are everything else—fire that burns, chemicals that sear, dust that asphyxiates.

Caroline Alexander's new translation of Homer's Iliad *will be published this year by Ecco Press. Longtime contributor Lynn Johnson was named one of five 2014-16 National Geographic photography fellows.*

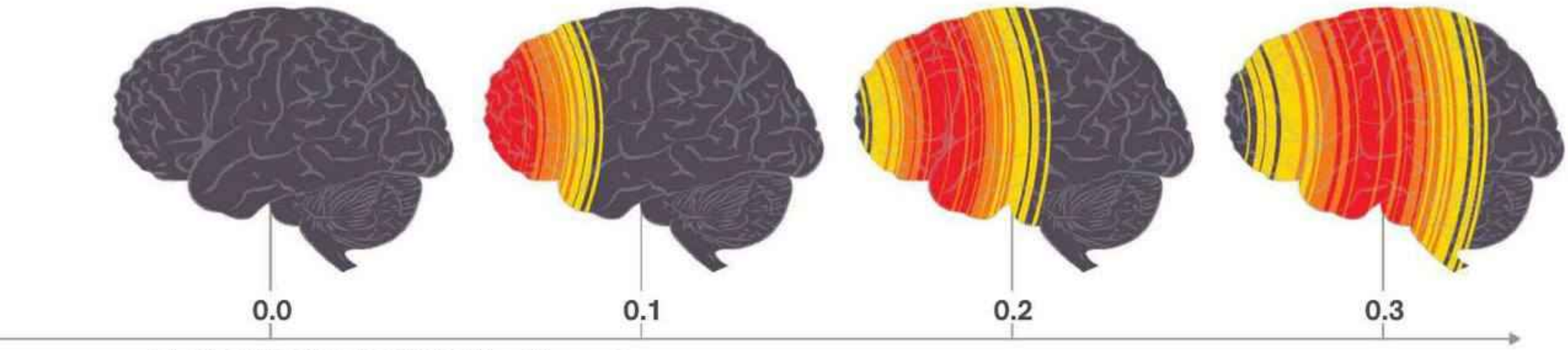
REBECCA HALE, NGM STAFF

Marines on patrol in Afghanistan in 2009 noticed a motorcyclist pass by, and moments later an IED exploded. “It’s like being kicked by a horse, a horse with a foot that could cover your entire body,” said one survivor of an IED attack.

PETER VAN AGTMAEL, MAGNUM PHOTOS

The mystery lies in the effects of the primary blast. Theories range wildly: Is it the shock wave’s entry to the brain through cranial orifices—eyes, nose, ears, mouth—that causes injury, and if so, how? Or is external shock pressure on the chest channeled inside vasculature up through the neck and into the brain? Does the transmission of complex wave activity by the skull into the semiliquid brain cause an embolism? Does pressure deform the skull, causing it to squeeze the brain? Is the explosive noise damaging? The flash of light? The majority of soldiers diagnosed with blast-induced neurotrauma have also been hurled or rattled by blast wind. Is military neurotrauma, then, simply an exotic form of concussion?

The tests in Colorado arose from a landmark 2008 study by the military of breachers, those soldiers whose job is to set explosives and who for years had been reported to suffer a high incidence of neurological symptoms. The study, conducted by the U.S. Marine Corps Weapons Training Battalion Dynamic Entry School, followed instructors and students over a two-week explosives training course. It turned out



Blast in the brain

Studies show that the key mechanical factors associated with brain injury are an increase in intracranial pressure and the brain's motion relative to the skull. The blast wave, or overpressure, affects the brain immediately upon impact with the skull. Pressure in the brain returns to normal after only a few milliseconds, but brain motion can occur for hundreds of milliseconds after impact.

that for days after the larger explosions, breachers reported dull aches in the chest and back "like someone had punched them," as well as headaches that "started with shooting pains in the forehead, progressed down the temples, behind the ears, and up through the jaw line."

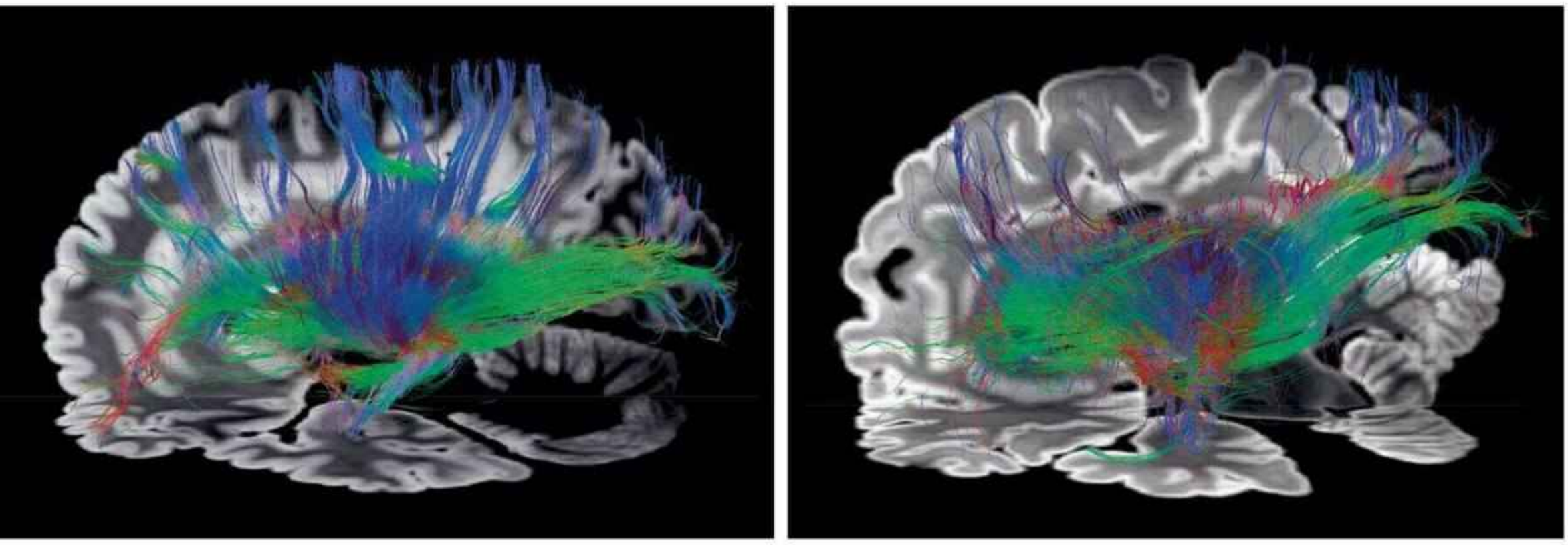
More significantly, neurobehavioral tests administered before and after the course showed a "slight indication of declining performance among the instructors," who typically are exposed to more blast events than students are. This suggested that repetitive exposure even to low-level blasts—even over just a two-week period—could be damaging.

The breacher study went some way toward bringing blast-induced neurotrauma into focus. As Lee Ann Young, one of the study's leaders, noted, it motivated six follow-on research initiatives that continue today. Previously, many in the military and medical communities had found it difficult to believe that a low-energy blast could inflict significant injury. "Our most recent experience was with Gulf War syndrome, where despite many efforts to find consistent threads, we came up mostly dry on specific causes," Col. Christian Macedonia (Ret.), the former medical sciences adviser to the chairman of the Joint Chiefs of Staff, told me. "So there were insane shouting matches in the Pentagon, strange as it may sound now, as to whether blast-related TBI actually existed." In a paper published as recently as 2008, researchers at the Center for Military Psychiatry and Neuroscience Research, Walter Reed Army Institute of Research, concluded that the troubling symptoms were strongly associated with PTSD and that "theoretical concern" about the neurological effects of blast exposure was essentially unfounded.

But today some researchers are floating a different theory: that mild TBI may increase vulnerability to certain psychological disorders, possibly accounting for the high rate of such disorders and even suicide among veterans. Many neurologists now advocate more precise terminology for this signature injury of the recent wars, such as "blast-induced traumatic brain injury" or "blast-induced neurotrauma"—and all I spoke with objected to the qualifier "mild."

IN THE BUNKER we waited for the smoke to clear, then ventured into still-singed air. The building's door had been blown off, the opposite wall was in splinters, the struts were broken, and much of the frame was askew. Pressure gauges at head and chest level had recorded the back-blast as it bounced off corners and walls. The explosion

JASON TREAT, NGM STAFF. SOURCE: ANDREW MERKLE, JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY



Broken connections

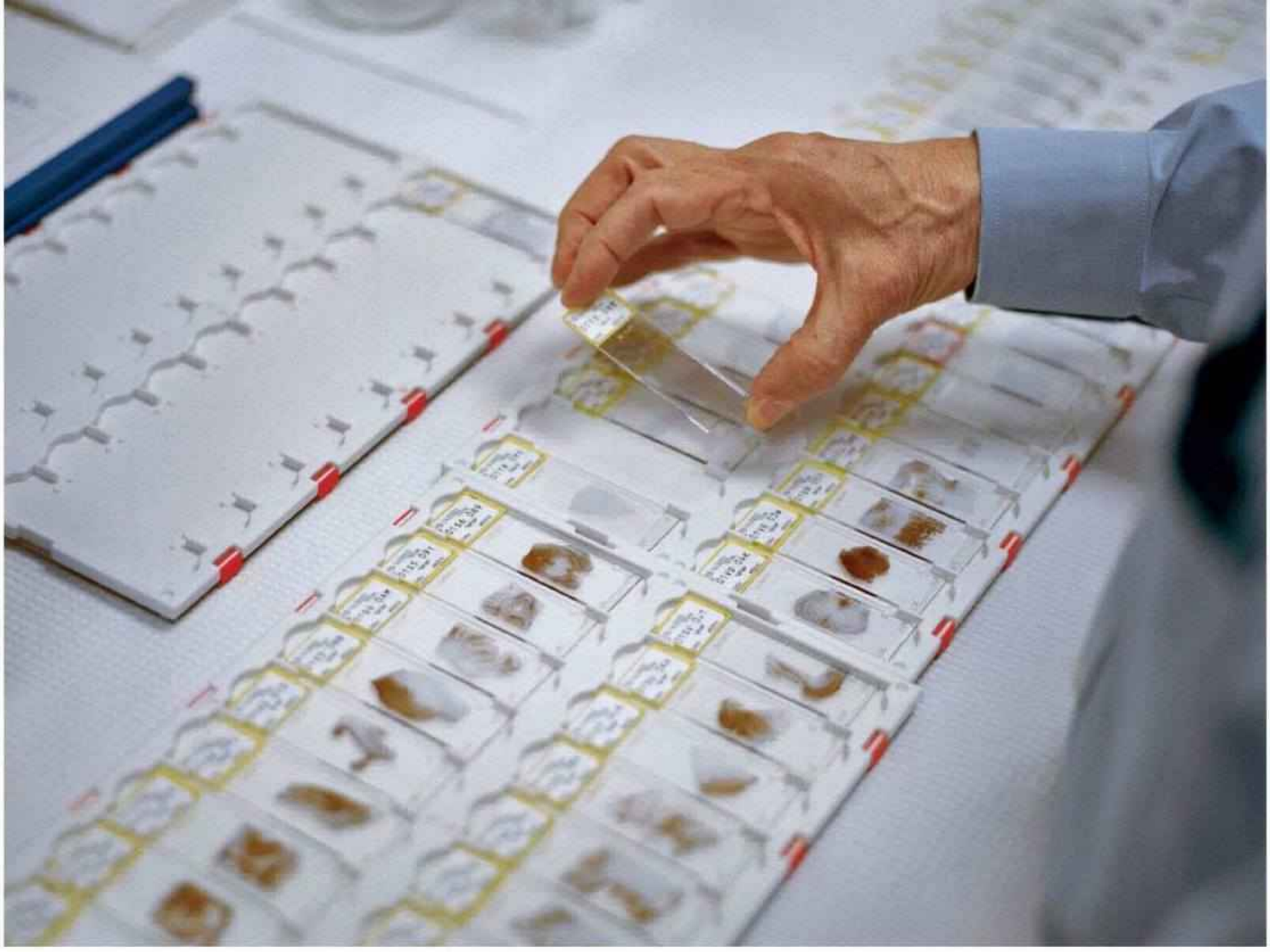
Diffusion tensor imaging tractography dramatically reveals the breakdown of neural connections in the brain of a civilian victim of severe traumatic brain injury (right), compared with a healthy brain (left). Researchers in the Military Brain Injury Studies Program at the Uniformed Services University of the Health Sciences plan to similarly map the brains of deceased veterans of recent campaigns to assess blast effects. Slides of delicate brain tissue (opposite) hold crucial clues. "I think I know what blast force does to the human brain," says program director Daniel Perl.

itself had been preserved on video, which replayed events, at two to three frames a second, that had flashed by at a speed of 14,000 frames a second—the ignited fuse glowing red-gold in a long, snaking, elegant stem of light, then the gold-black bloom of the explosion: *BOOM*.

Shot 52 was one of a series intended to cast light on the phenomenon of back-blast, the reflection of blast pressure off a surface. Other studies are examining the length of blast exposure and the frequency and type of blast. On site to lead the analysis was Charles Needham, a world authority on blast physics. Studying a computer-generated graph, he traced the spikes and dips of pressure that oscillated through five cycles before flattening out. The entire sequence lasted some 65 milliseconds. One hundred milliseconds is the minimum time it takes for a human to react to any stimulus—it had taken less than five milliseconds for the shock wave to hit the gauges on the walls. As Needham pointed out, "Anywhere in that room—it's on you."

Fatherly in manner, with white hair and a full white beard, Needham had been described to me by a colleague as a "cross between Santa Claus and Eeyore," an impression that belied his stature as a high wizard in the black art of explosives. With degrees in physics and astrophysics, he is an authority on modeling all variety of blast events and the dynamics of blast reflection, and he spoke with wistful nostalgia of the big "rumble booms" of high-ordnance tests of years past. A glance at his résumé calls attention to the diversity and sheer spookiness of blast-related issues: "modifications to fireball behavior," "high explosive simulation of nuclear effects," and "Shock and Vibration symposia."

Needham's objective was to provide breachers with maps that would show which areas of a given type of structure are safest from reflected pressure. How a blast is reflected is determined not only by whether a space is square or rectangular, and the ceiling high or low, but also by where the wall studs lie, the number and placement of doors and windows, whether there are gaps or holes in the enclosure, whether there is furniture in the room. A shock wave bouncing off a rigid surface, whether of thin plaster or of steel, can be more powerful than the original wave. (Notoriously, the back-blast reflected off the ground at Hiroshima was more powerful than the actual explosion.) The corners of a room, where one might instinctively seek shelter, are particularly dangerous—as is being the third man in a line of breachers carrying protective shields, which, as it turns out,



also reflect shock waves. A blast even reflects from within a soldier's helmet to his head. Every feature in a landscape, every gesture a person makes, shapes a blast event.

A terse conclusion of the original 2008 breacher injury study cited "clear evidence" that recommended safe standoff distances required revision. "We…found errors of more than a factor of two in some of those training manuals," Needham said, referring to breacher instructions: As a result, the manuals were modified in 2012. Encompassing a multitude of variables, calculations about blast events are elaborately difficult, and only in recent years has it been possible to make the kind of models Needham is now devising. "These are large calculations and take a lot of computer time," he said. Or, as another blast authority put it, "Until very recently, the dominant force that caused all this damage was basically magic."

KEEN INTEREST IN BLAST EFFECTS began in World War I, when the signature mechanism of injury was—as in the wars in Iraq and Afghanistan—blast force, mostly in the form of exploding artillery shells. The term "shell shock" first appeared in February 1915 in an article in the *Lancet* that examined the case studies of three British soldiers exposed to blast events who complained of sleeplessness, reduced visual field, and loss of taste, hearing, and memory. Initially their affliction was believed to be a "commotional disorder," referring to agitation of the brain caused by a blast shock wave. A leading theory was that the shock wave traveled to the brain through spinal fluid.

But as the war continued, the condition was attributed to weakness of nerves, given the fact that many men appeared to be otherwise uninjured. The term "shell shock," implying that the shell burst itself was the cause of the damage, fell out of favor. The revision of diagnosis had profound consequences. In the following decades the shell-shocked soldier came to symbolize the emotional damage that is the cost of war, and medical research ceased to investigate the possibility that blast-force injury might be physical. "When I was in medical school, we were told about shell shock in World War I, that people then believed the brain could be damaged by blast waves from exploding shells," Colonel Macedonia said. "It was told as a story about how ignorant the medical profession was a hundred years ago."

The shell-shocked soldiers of that war can be tracked through British Ministry of Pension files into the 1920s, '30s, '40s, and beyond. Case reports give details of veterans sunk in lethargy

Army Staff Sgt. Perry Hopman
Iraq 2006-08

Wearing his mask—half patriotic, half death's-head—Hopman confronts the battery of medications he takes daily for blast-force injuries he sustained while treating soldiers as a flight medic. "I know my name, but I don't know the man who used to back up that name…I never thought I would have to set a reminder to take a shower, you know. I'm 39 years old. I've got to set a reminder to take medicine, set a reminder to do anything… My daughter, she's only four, so this is the only dad she's ever known, whereas my son knew me before."


HOPMAN
U.S. ARMY

events. Oxen, sheep, pigs, goats, dogs, cats, monkeys, rats, hamsters, rabbits, mice, and guinea pigs were subjected to live blasts or placed in shock tubes. (A shock tube is a long tube fitted with an internal membrane through which pressurized air bursts. This lab simulation, stripped of heat, debris, chemical fallout, and back-blast variables, creates a "pure" blast shock wave.) In the early 1980s the focus of research shifted from nuclear blasts to the low-level explosives characteristic of today's war theaters.

"MOST OF OUR MEDICAL RESEARCH on blast injuries was either on fragmentation wounds or what happens in gas-filled organs—everyone was always concerned in a thermonuclear explosion what happened to your lungs and your gastrointestinal tract," Lt. Col. Kevin "Kit" Parker, the Tarr Family Professor of Bioengineering and Applied Physics at Harvard, told me. "We completely overlooked the brain. Today the enemy has developed a weapon system that is targeted toward our scientific weak spot."

Parker, a towering figure with a shaved head and booming voice, is also a former U.S. Army infantry officer who served two tours in Afghanistan, where he saw and felt the effects of blast force. "There was a flash in the sky, and I turned back toward the mountains where the fighting was," Parker said, recalling the day in January 2003 when, in the hills of Kandahar, the shock wave from a distant explosion passed through his body. "It just felt like it lifted my innards and put them back down."

Mostly he was made aware of the range of damage blast inflicted. "When bombs are going off, it's easier to forget about the guy who's been a little out of sorts than the guy who's sitting near him and got both his legs blown off," Parker said. "But the guy who's going to have the more serious long-term issues probably is going to be the guy who had the brain injury."

The shock wave from a distant explosion "felt like it lifted my innards and put them back down." —Kevin Parker

In 2005 Parker, who was then involved in cardiac tissue engineering, turned his attention to blast-induced neurotrauma. He began by reviewing the science for a class of proteins—integrins—that transmit mechanical forces into cells. Using specially designed magnetic tweezers and a device resembling a miniature jackhammer to simulate the abrupt stretching and high-velocity compression of blast effects, Parker and a small team of students subjected engineered tissues of rat neurons, or nerve cells, to blastlike assault. The integrins on the cell surface initiated a cascade of effects culminating in a dramatic retraction of axons, the long tendrils that serve as a neuron's signaling mechanism.

By working at the cellular level, Parker's team sidestepped two central difficulties of any blast research—namely, that one cannot expose humans to blast events and that animals are poor substitutes for humans. On the other

hand, results from cells in a petri dish cannot be extrapolated to a human being.

THE ARRAY OF THEORIES neurologists are actively pursuing stands as eloquent testimony to how wide open blast-induced neurotrauma research is. Lee Goldstein, of Boston University School of Medicine, has taken a very different approach. "People focus on the pressure wave," Goldstein told me. "What's behind it is the wind." Goldstein's range of expertise can be read in his full title: associate professor of psychiatry, neurology, ophthalmology, pathology and laboratory medicine, and biomedical, computer, and electrical engineering. At 52, he has the lean build, long dark hair and beard, and intensity of purpose of a desert prophet.

In May 2012 he published the results of studies that examined a possible association between blast-induced neurotrauma and chronic traumatic encephalopathy (CTE), a neurodegenerative disease that he and his team discovered in the autopsied brains of four military veterans with blast exposure. Goldstein's co-author, Ann McKee, of VA Boston, had been studying CTE in the autopsied brains of football players and other athletes. First reported as a "punch drunk" syndrome in boxers in 1928, CTE is associated with athletes who sustain repetitive head trauma. An incurable and ultimately fatal neurodegenerative disease, CTE leads to cognitive disability and dementia. The disease can be detected only at autopsy and is revealed by abnormal tangles of a protein called tau.

To test the theory that blast exposure may have triggered CTE pathology, Goldstein's team exposed mice to a single shock-tube blast that simulated the effects of a moderate-size explosive. High-speed cameras captured the results—a rapid bobblehead effect, as the heads of the mice shook back and forth in reaction to the force. In 30 milliseconds, far less than the blink of an eye, the oscillating wind had spiked and dipped nine times. "In one blast you're really getting multiple hits," Goldstein said. "So it's like you're packing a whole bunch of hits into a very short time."

Two weeks after exposure to the blast, the mice brains showed an accumulation of chemically modified tau protein and other damage. Critics of the study, however, point out that three of the four human cases that inspired the shock-tube experiments had experienced additional trauma unrelated to blast and that tests on mannequin models indicated that the bobblehead effect was not usual in the field.

Some researchers believe that it's a mistake to focus only on the head. "The whole body is exposed to huge kinetic energy," said Ibolja Cernak, describing the impact of a blast event. "Athletes do not have this kind of whole body exposure." The chair of Canadian military and veterans' clinical rehabilitation research at the University of Alberta, Cernak began her research on the battlefields of Kosovo, when she noticed that some soldiers and civilians exposed to blast exhibited symptoms reminiscent of certain neurodegenerative diseases. The blast pressure wave hits the chest and abdomen "like a huge fist," Cernak says, transferring its kinetic energy to the body. "That kinetic energy generates oscillating pressure waves in the blood, which serves as a perfect medium to further transfer that kinetic energy to all organs, including the brain."

Experiments she conducted on mice revealed that inflammation occurred in the brain whether the head had been protected from blast or not—inflammation, she argues, that starts a process of damage comparable to that seen in Alzheimer's disease. By contrast, protection of the thorax significantly reduced inflammation in the brain, suggesting that the blast-body interaction has a crucial role in blast-induced brain injury.

AS OF NOW, the only wholly reliable method of directly examining the biological effects of blast force on the human brain is autopsy. In 2013 the Department of Defense established a brain tissue repository to advance the study of blast-induced neurotrauma in service members. Overseen by Daniel Perl, professor of pathology at the Uniformed Services University of the Health Sciences, in Bethesda, Maryland, the repository has been receiving brains donated by service members' families. This has allowed researchers, Perl

BEHIND THE MASK

At the National Intrepid Center of Excellence (NICoE), part of Walter Reed National Military Medical Center, in Bethesda, Maryland, treatment for traumatic brain injury and psychological health concerns—including post-traumatic stress disorder—draws on an interdisciplinary care model that incorporates traditional and alternative medicine. Art therapist Melissa Walker works with service members to create masks that illustrate hidden feelings. A number of themes occur repeatedly in their choice of images, among them death (often represented by skulls), inability to express themselves (mouths stitched, gagged, or locked shut), physical pain (facial wounds), and patriotic feelings (American flags).

"I thought this was a joke," recalled Sergeant Hopman. "I wanted no part of it because, number one, I'm a man, and I don't like holding a dainty little paintbrush. Number two, I'm not an artist. And number three, I'm not in kindergarten. Well, I was ignorant, and I was wrong, because it's great. I think this is what started me kind of opening up and talking about stuff and actually trying to get better."

REBECCA HALE (ALL)


PTSD
HEAL


COMFORTABLY
NUMB

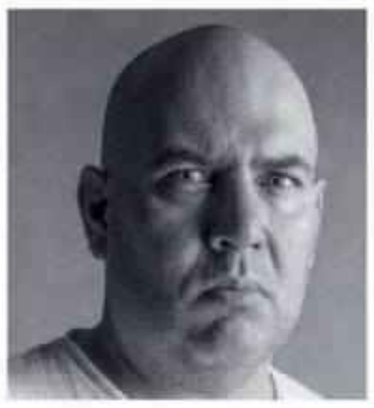
Marine Gunnery Sgt. Aaron Tam (Ret.)
Iraq 2004-05, 2007-08

"Detonation happened, and I was right there in the blast seat. I got blown up. And all this medical study—nobody ever thought that they [blast events] were very harmful, and so we didn't log them, which we should because all blast forces are cumulative to the body. On a grade number for me, it would probably be 300-plus explosions . . . I'm not going to not play with my children. I'm not going to let my injuries stop them from having a good life."

PHOTOGRAPHED WITH HIS WIFE, ANGELA, AND THEIR TWO CHILDREN

Marine Gunnery Sgt. Tiffany H.
Iraq 2007-08, Afghanistan 2010-11

Tiffany H., as she prefers to be known, was “blown up” while helping women in a remote Afghan village earn additional income for their families. Memory loss, balance difficulties, and anxiety are among her many symptoms. The blinded eye and sealed lips on her mask are common symbols used by blast-injured soldiers.



Army Maj. Jeff Hall (Ret.)
Iraq 2003-04, 2005

Sheri Hall: "I told him, 'I'm not cleaning your mess. I'm not cleaning your brains off the bedroom wall. You kill yourself, you better leave a lengthy explanation as to why, because I can't explain to your kids, to your girls who love you, why you would make such a mess of our lives.' Still, to this day I wake up some mornings and go, OK, what's today going to be like? How's Jeff going to be when he wakes? You know, how's he going to be after his first cup of coffee? How's it going to be for him today? I know he dreads going to work every day. There's that anxiety that goes with that. How bad is it going to be? What can I do to set the morning off on a good foot? So I do still think about that every day, but I don't walk around on eggshells anymore."

PHOTOGRAPHED WITH HIS WIFE, SHERI (AT LEFT), AND THEIR TWO DAUGHTERS

says, to get "to the tissue level to really see what's going on." As he points out, magnetic resonance imaging (MRI) of the living brain has a resolution a thousand times less than what can be seen when the brain is examined under a microscope.

Perl's expertise extends from work on CTE, Alzheimer's, and other age-related neurodegenerative diseases to research on a unique complex of neurological disorders in a small population in Guam (a mystery described in Oliver Sacks's popular book *The Island of the Colorblind*). Perl has also written of shell shock and its relationship to modern blast-induced brain injuries, noting that despite a hundred years' use of explosive force in warfare, there have been "no detailed neuropathology studies…in the human brain after blast exposure."

Now, 18 months into the brain tissue study, Perl said he's seeing revelatory results. "We believe we're getting close to identifying unique changes in the brains of blast-exposed soldiers that are not seen in brain injuries of civilians," he said, referring to common blunt-force trauma such as athletes sustain. "What we're seeing appears to be unique to blast. This is an injury that appears to be unique to military experience."

If he's correct, the findings will have major implications not only for treatment but also for diagnosis and prevention. "I think we'll have to sit down with the helmet-design people and the body-armor people," he predicted. "A lot of designs were based on very different assumptions."

For living soldiers, meanwhile, reliable methods of diagnosis remain tragically elusive. In June 2011 the *New England Journal of Medicine* published the results of a study that for the first time succeeded in detecting structural abnormalities in the brains of blast-exposed soldiers by using an advanced form of MRI. Although hailed as a landmark in an accompanying editorial, the paper was weakened by the fact that every participant had also experienced other traumas, such as being struck by a blunt object or being in a motor vehicle crash.

A number of studies investigating possible biomarkers may have findings that will aid future diagnosis: A blood test for unique protein markers indicative of brain cell damage has proved promising, for example, and is now being tested by the military. (It is effective only if administered within a few days of the injury.) And in 2014 a small study of 52 veterans successfully used an MRI technique called macromolecular proton fraction (MPF) mapping, which examines levels of myelin, a major component of brain white matter; MPF mapping has been used to study patients with multiple sclerosis, who have reduced levels of myelin, the fatty sheathing that protects and insulates neurons. Evidence of brain white-matter damage was detected in 34 veterans with exposure to one or more blast events, compared with 18 veterans without blast exposure.

"We'd told the veterans to give us their best estimates of how many blast-related mild traumatic brain injuries they had sustained during their military careers," said Eric Petrie, a professor of psychiatry at the University of Washington and the lead author of the study. "But how accurately can veterans recall these events? Some in the study were five to six years out from the time of their last blast exposure," he said, summing up one of the fundamental problems of all diagnostic studies that depend on self-reporting.

"What we're seeing appears to be unique to blast—an injury unique to military experience." **—Daniel Perl**

In the future, photonic crystalline materials that change color when exposed to blast waves, worn as stickers on uniforms and helmets, may provide an objective measurement of blast exposure.

Despite the array of promising strategies, for the time being diagnosis still depends, as it did in WWI, on clinical assessment, which may now involve computer-administered examinations such as the Automated Neuropsychological Assessment Metrics: "Did you experience any of the following: Dazed, confused, saw stars? How much does this word describe how you feel? 'Shaky.'"

COMPLEX AS IT MAY BE, a blast event can be created for very little money and with minimal expertise. Explosively formed penetrators, a type of IED used to pierce armored vehicles, can be assembled for a few dollars. Disks that become bullet-shaped and molten hot as they fly through the air, these explosive projectiles can, in the words of one ordnance expert, cut through an armored car "like a hot butter knife." In this way 25 dollars' worth of technology can take out a million-dollar armored vehicle and kill or inflict grievous injury on the soldiers in it. The cost of their medical care—possibly over decades—will add significantly to the economic disparity. Given this cost-effectiveness, explosive force is likely to remain a signature weapon of modern warfare.

Today, while researchers strive to figure out what goes on when blast force encounters the human brain, untold numbers of soldiers are struggling with the aftermath of their own encounters.

BOOM. On patrol in Iraq in 2009, Robert Anetz felt the immense pressure against his body. Then everything went numb. "Everybody started shouting, 'Are you good? Are you good?' You check for blood," Anetz said. There was no blood, so he thought he was good. But seven months after returning from Iraq, he had a seizure while driving, and a grand mal seizure six months after that. Now rebuilding his life as a student and volunteer firefighter, his daunting regimen of 15 different medications is down to three, but the headaches and migraines have not gone away.

Enrique Trevino, who at the age of 21 survived a massive IED ambush in Afghanistan one night two weeks before he was to return home, remembers only the bright flash and his buddies screaming his name. "I'll never forget that flash," he said. "It almost looked like a lightning strike." When he finally awoke in Fort Hood, Texas, he learned the explosion that had knocked out his night optics had also knocked out his power of speech and his peripheral vision. He now works to rebuild his mind with mental tasks like counting backward from 50, but he suffers daily from migraines and nightly from his dreams.

About a year after his return home, Trevino said, "it all came crashing down on me." He survived a suicide attempt. A friend of his who had also served in Afghanistan did not. "They found him in his home," Trevino said. "He, he—nobody would have ever thought—nobody would have ever been—nobody ever, nobody, no one, nobody saw that. Nobody saw."

And nobody saw it for my brother-in-law, Ron Haskins, from whom I first learned about breachers. After retiring from the Army Special Forces, he worked with a private security force in Iraq. He sustained two IED attacks that left him with headaches and ringing in his ears so loud he was unable to sleep. On his return to the United States, he worked for the Department of Homeland Security and conducted breacher training courses for a security company of his own. One night in the summer of 2011, for reasons no one could fathom, he picked up a gun and ended his life.

"We should get you guys to come out to New Mexico so you can see the devices, have explosions go off," Ron had told me about a training course he led. "You'll be half a mile away, and you'll be amazed at how a couple of pounds will rattle the earth around you." □

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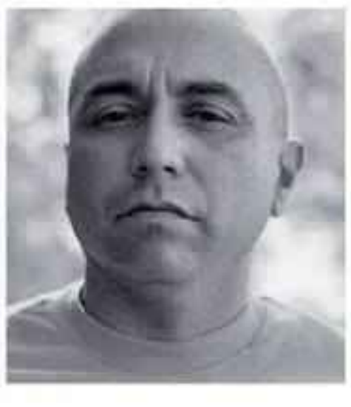
MULTIMEDIA

"If my hand or arm had just been blown off, then people would understand. They'd see there's something wrong."

—DAVID GRIEGO

Air Force Staff Sgt. Robert "Bo" Wester (Ret.)
Iraq 2007, 2008-09, Afghanistan 2010

Suiting up before attempting ordnance disposal "is the last line. There's no one else to call . . . It's the person and the IED . . . and if a mistake is made at that point, then death is almost certain. They call it the long walk because once you get that bomb suit on, number one, everything is harder when you're wearing that 100 pounds . . . Two, the stress of knowing what you're about to do. And three, it's quiet, and it seems like it takes an hour to walk."



Army First Sgt. David Griego
Iraq 2008, Afghanistan 2012

"One bad thing about the NICoE [program] is that you have to talk about what happened. And so one of the things I know—and not to deter you from asking questions here—but any time I have to talk about it for a while, I can tell I may have or may not have some images and nightmares tonight…Sometimes you find yourself saying, I wish I had lost a body part, so people will see—they'll get it."

PHOTOGRAPHED WITH HIS WIFE, TRACY

Best friends Ha'a Keaulana, at right, and Maili Makana dive under a wave on their way to a surfing spot near their hometown of Makaha. Like generations before them, they visit these waters almost every day to refresh both body and spirit.

Pure Hawaiian

Beyond the glitz of tourist beaches, locals cling to the spirit of the ocean.

It takes an expert to ride the famous Pipeline, where jagged coral lurks just below the surface. Competitive surfers come here, to the North Shore of Oahu, from around the world. The vibe at Makaha, on the west coast, is more about the families that live there.

By John Lancaster
Photographs by Paul Nicklen

In the islands where surfing began, the waves on that particular day were a disappointment—mushy, chest high, and annoyingly infrequent. Still, Hawaiians have never needed much of an excuse to grab a board and hit the ocean, and the takeoff zone was packed. Teens on shortboards. Moms on longboards. Grade-schoolers on bodyboards. A guy with a gray ponytail on a stand-up paddleboard. Some had tribal tattoos in the style of Polynesian warriors. Straddling my surfboard in the deep water beside the reef, I surveyed the crowd with a knot in my stomach, feeling that I didn't belong.

Makaha has long been known as a beach where haoles, a Hawaiian term for white people and other outsiders, venture at their peril. Located on Oahu's west coast, far from the glitzy North Shore crowds of Sunset Beach or Pipeline or the package tourists at Waikiki Beach, it has a reputation as a tightly cloistered community dominated by descendants of the ancient Polynesian seafarers who settled the islands.

Even those Makaha residents who have come to terms with the United States takeover of Hawaii in 1898—and some still have not—are determined to prevent the same thing from happening to their waves. Stories are legion of visiting surfers being chased from the water here, a few with broken noses, after breaching some unwritten rule. I was eager to avoid the same fate.

For half an hour I floated near the takeoff zone, waiting for my chance, before I finally spotted what appeared to be an unclaimed wave. I spun my board toward the beach and paddled hard. But just as I gained speed, a stone-faced teenager on a bodyboard finned up the same wave. He planted his hand firmly on my shoulder and pushed me off the wave, simultaneously propelling himself down its face. I gave up and paddled in. So much for "aloha," I thought.

But over several weeks in Makaha I came to grasp that what looked like thuggish protectionism was in fact more complicated. Hawaiians, after all, are the original surfing fanatics, having embraced the sport since roughly the time of the Crusades. They are also, in some sense, survivors. Since the coming of the first white men in the late 18th century, their history has been colored by loss—first of numbers, as imported diseases burned through their ranks, then of land, nationhood, and culture. Even hula dancing all but vanished. For Hawaiians—an increasingly imprecise term after waves of immigration to the islands and generations of intermarriage—surfing is a tangible link to the precolonial past and a last remaining shard of cultural identity. It's also a testament to Hawaiians' almost

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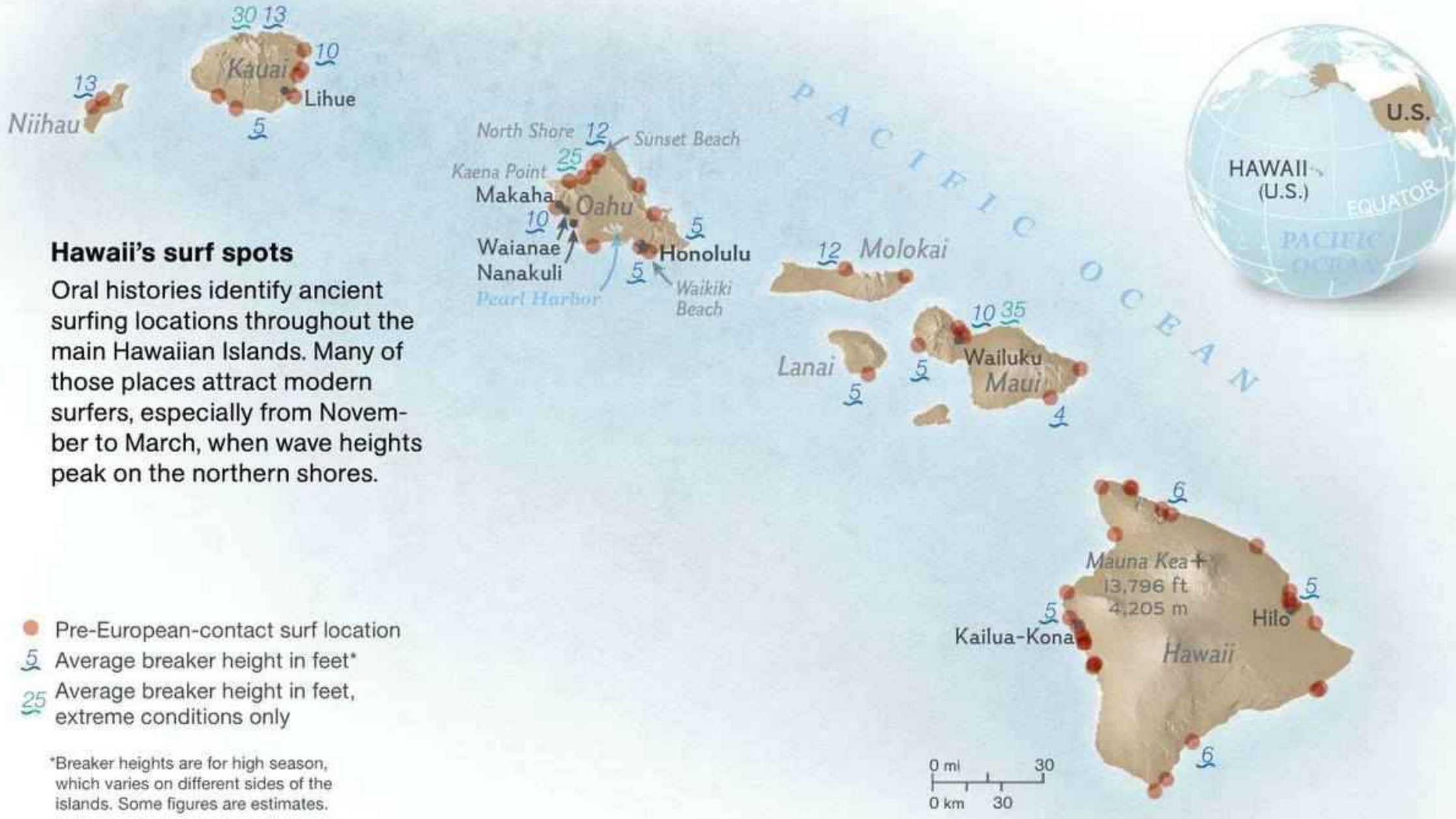
John Lancaster profiled Kazakhstan's capital, Astana, in the February 2012 issue. Photographer Paul Nicklen's most recent story was "Yukon: Canada's Wild West," for the February 2014 issue.

Wearing a malo, or loincloth, construction worker Keli‘iokalani Makua reveals traditional tattoos that tell his life story. Body art is a popular sign of Hawaiian identity, but including the face is rare.



Hawaii's surf spots

Oral histories identify ancient surfing locations throughout the main Hawaiian Islands. Many of those places attract modern surfers, especially from November to March, when wave heights peak on the northern shores.

- Pre-European-contact surf location
- 5 Average breaker height in feet*
- 25 Average breaker height in feet, extreme conditions only

*Breaker heights are for high season, which varies on different sides of the islands. Some figures are estimates.

mystical connection to the ocean. No wonder they can get a little prickly about their waves.

"We got nice people here, but if you treat them bad, they'll treat you bad." It wasn't a threat, just a simple statement of fact. The man who uttered it was sitting on a tree limb that had washed up on the beach. Though well past retirement age, he looked like someone you didn't want to cross, a thick-chested guy in board shorts, sunglasses, and a black sun visor. His hair was a luxuriant white, and the slablike planes of his face evoked the ancient Hawaiian alii, or chiefs, he counts among his forebears.

"The guys, if they tell you they're going to do something to you, they will do something to you," he said. "Just remember where you're at."

On the subject of Makaha and its customs, there is no higher authority than Richard "Buffalo" Keaulana, a rare full-blooded Hawaiian who has spent most of his 80 years on Oahu's West Side. His standing in the community is closely linked to the ocean. Keaulana was a preternaturally gifted surfer as well as Makaha's first full-time lifeguard and the founder of a well-known surfing competition called the Buffalo Big Board Surfing Classic. He remains the most prominent of Makaha's famous "uncles"—the mostly Hawaiian elders who serve as guardians of the community—and is revered throughout the islands as the apotheosis of the "waterman," an aquatic all-rounder who combines reverence for the ocean with deep knowledge, skill, and courage. "Last of the traditionalists," one admirer told me.

The waterman ethos dates to the first Hawaiians, who are believed to have sailed to the islands in double-hulled canoes from the Marquesas around A.D. 700, followed by similar mariners from Tahiti five centuries later. These settlers probably brought with them some familiarity with surfing, at least in rudimentary form, but only in their new homeland did the sport become an important part of the culture, embraced by chiefs and commoners of both genders on most of Hawaii's eight major islands. There were surfing temples, surfing deities, surfing contests with crowds of onlookers gambling on the outcome. The royals rode massive *olo* boards hewed from the wood of the wiliwili or the koa tree, while their subjects typically

JEROME N. COOKSON, NGM STAFF; PATRICIA HEALY
SOURCES: JOHN CLARK; PAT CALDWELL, NOAA'S NATIONAL OCEANOGRAPHIC DATA CENTER

surfed on shorter, thinner *alaia* boards. A new swell could empty a village for days.

New England missionaries, who followed the 1778 landing of British explorer James Cook, often have been blamed for putting a damper on the sport the natives called *he'e nalu*. Their principal objection, it seems, was to the locals' preference for surfing in the nude. Far more harmful to surfing, as to Hawaiian society itself, was the arrival of European diseases such as smallpox. By the time Congress formally annexed Hawaii in 1898, the native population had fallen to about 40,000 from as many as 800,000 at the time of Cook's landing.

The bitter legacy of colonization left an indelible stamp on Hawaiians of Keaulana's generation. He spent his childhood in poverty, much of it on state-provided "homestead" land—Hawaii's version of an Indian reservation—in the West Side community of Nanakuli. The native language had been purged from public schools in favor of English, though in practice the locals spoke pidgin, an English-based creole still common in the area.

Keaulana ran away from home at the age of ten, after his abusive stepfather chased him into a taro plot with a knife. He bounced among relatives and friends, dropped out of school after the eighth grade, and endured periods of homelessness, sleeping in cardboard boxes and stealing chickens to survive.

The ocean proved his salvation—"a place to get away," he called it. A powerful swimmer, he learned to fish with a speargun made from a sharpened coat hanger and a length of rubber tubing. As a teenager, he worked as a diver, unsnagging the nets of Filipino fishing sampans from coral reefs. Then he discovered surfing.

Of course Keaulana wasn't entirely unfamiliar with the sport that had so obsessed his ancestors. Since the turn of the century Hawaiian beachboys had been teaching tourists how to surf on the gentle breakers of Waikiki, and during Keaulana's childhood a few Hawaiians could still be found riding V-bottom redwood boards on a break near Nanakuli. He learned to surf on a crude surfboard made from glued-together railroad ties. But he didn't truly embrace the sport until he fell in with a handful of pioneering haole surfers, some from California, who arrived at Makaha in the early 1950s.

The newcomers rode lightweight boards made from fiberglass and balsa wood (soon replaced with polystyrene foam) and outfitted with fins so they could be turned easily. Makaha became a laboratory for new surfing techniques and board designs as well as the setting for what was billed as the first international surfing contest, in 1954. Keaulana joined the party and soon emerged as one of the best surfers of his generation, with a fluid, ambidextrous style that he would later showcase in surfing movies and contests as far away as Peru.

Makaha became a laboratory for new surfing techniques and board designs.

After stints in the Army and as a beachboy at Waikiki, Keaulana returned to Makaha in 1960 with a wife and a job as parkkeeper and then lifeguard, bringing up four children in an apartment above a public bathhouse on the beach. Eventually Keaulana was able to build a house, after he rescued a wealthy Texan who was knocked senseless while surfing in big waves. The man gave Keaulana $30,000 as an expression of gratitude.

Keaulana's renowned waterman skills earned him a prominent role in the Hawaiian cultural and political awakening that came to be known as the Second Hawaiian Renaissance. In 1977 he kicked off his eponymous surfing contest, whose party atmosphere and multiple events—canoe surfing, tandem surfing, longboarding—recall the ancient Makahiki festival held in honor of the Hawaiian god Lono. Keaulana's chieflike status was enhanced by his burly physique and, when necessary, "a look that chills your bones," in the words of his eldest son, Brian, who added, "Every local kid knows that look."

At the same time, "Uncle Buff" was nothing if


SUBWAY

In his workshop at home in Makaha, retired bus driver Bruce DeSoto sculpts a foam board by hand. “My shaping is pretty old style,” he says. “Nowadays there are computers that shape the boards. They pop them out in factories.”

Evoking the original community spirit of surf-riding, paddlers work together to catch a wave with an inflatable board called a Supsquatch. On flat water “you can just go sightseeing, enjoy it with your family,” says Eli Smith, steering at the back.

not pragmatic, as he showed in the running of his contest. Tourists who drove up from Honolulu often returned to their rental cars to find windows smashed and wallets missing. "That's the stupid thing they do. They bring a lot of money," Keaulana said. So he identified the locals responsible for the break-ins—"all the thieves and make-trouble guys"—and hired them as security guards. The thefts mostly stopped.

In recent years resorts have begun spreading up the West Side, and vacation homes have sprouted amid the modest plantation-style houses that cluster on either end of Makaha's golden beach. But in other ways little has changed. At a beachside picnic table in the shade of a *milo* tree, Keaulana and his fellow uncles

For the most part this is not the Hawaii of tourist brochures.

while away the hours "talking story" or playing dominoes, and outsiders are received warily, at least at first. "You got any ID?" one of the uncles demanded when I first appeared with my notebook and questions. I later asked the same man if he worried about the influx of nonlocals competing for waves, and he assured me that he didn't. "We regulate that to death, brah."

THE COMMUNITIES collectively known as the West Side are situated along Oahu's Farrington Highway, which begins west of Pearl Harbor and passes through Makaha before terminating near the island's northwestern tip, called Kaena Point. Running along the base of the Waianae Range, it's a rain-starved coastal strip that's one of the oldest settled parts of Oahu. Here and there are ruins of stone temples and fishponds, along with more contemporary echoes of Hawaii's past: roadside stands selling *poke* (raw fish) and laulaus (pork wrapped in taro leaves), outrigger canoes hauled up on the beach at Pokai Bay. But for the most part this is not the Hawaii of tourist brochures.

In the main town of Waianae the highway is lined with fast-food outlets, pawnshops, and scruffy shopping plazas. Homeless people camp in a thicket near the boat basin. I went to Waianae to meet one of Keaulana's "make-trouble guys," a surfing prodigy with a troubled past named Sheldon Paishon.

I turned in to a neighborhood of ramshackle houses, one of which had a bedsheet hanging in the front door. Paishon poked his head through the opening and joined me in my car.

Born on the West Side in 1993, Paishon had a painfully thin build and a crest of floppy, sun-bleached hair that he calls a "frohawk." I asked whether he wanted breakfast. He declined, explaining that he had eaten well the night before. He told me that his mother had been panhandling at the Waianae Mall, where someone had bought her a bucket of Kentucky Fried Chicken that she brought home to her family. "She met the right person," Paishon said. "She got blessed."

We drove north to Makaha, stopping briefly so that Paishon could retrieve his surfboard of the moment—a sorry-looking thing with a busted-off nose—from the bushes where he'd stashed it the day before. We continued in the same direction and a few minutes later parked along the beach at Yokohama Bay.

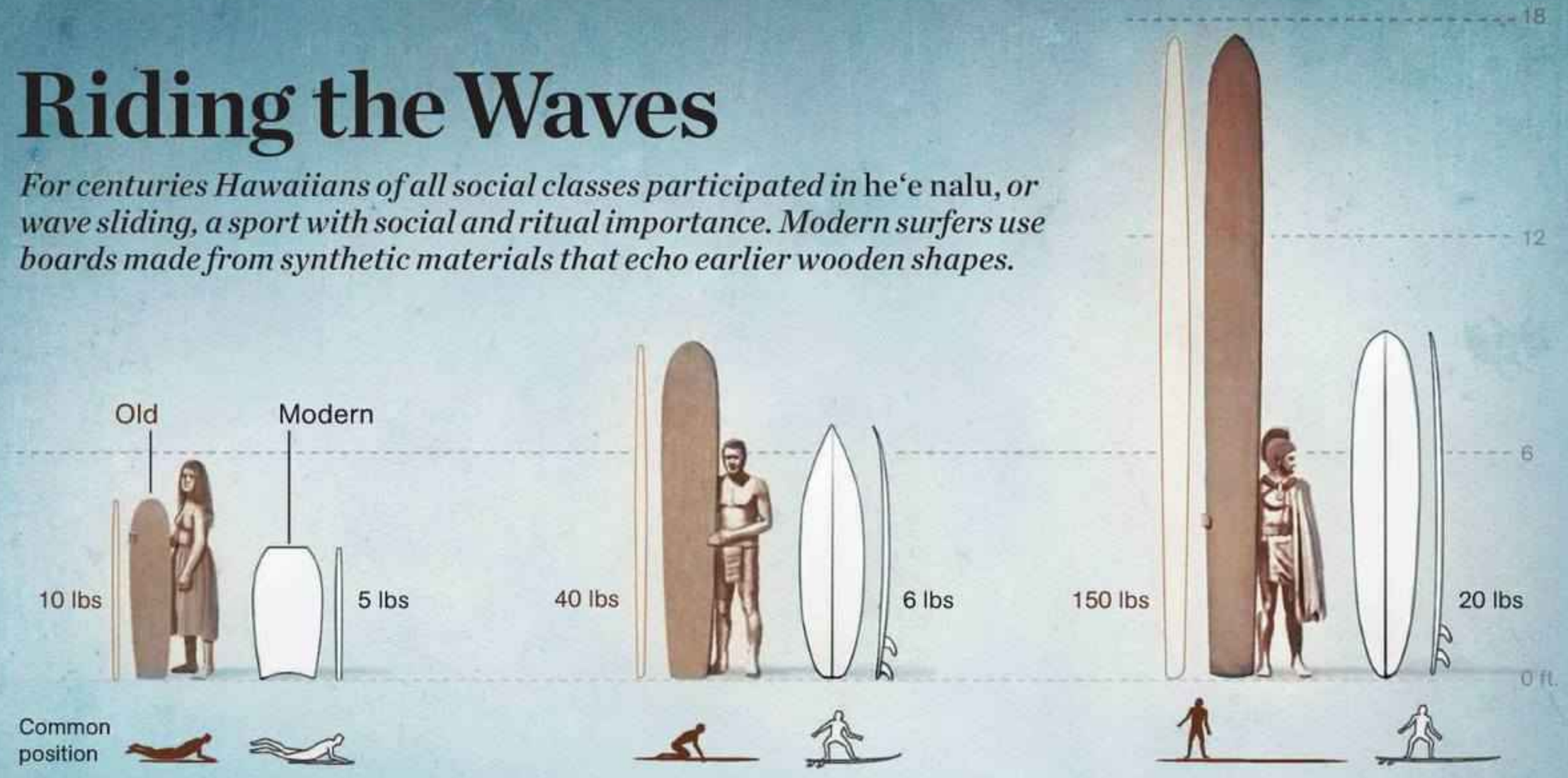
"Yokes" is considered the heaviest break on the West Side, and on this morning it was easy to see why. Thick, powerful waves unfurled across a shallow reef. But Paishon didn't hesitate before joining the dozen or so surfers already in the water, and within moments he was dominating the field. Effortless, devil-may-care takeoffs, casual tube rides, soaring aerial maneuvers—he surfed with a grace and audacity I had rarely seen outside of pro-surfing videos. After half an hour, he snapped his board in half and swam back to the beach, holding a piece of it in one hand.

A lifeguard who had been watching wagged his head and observed, "You shouldn't judge a fish by his ability to climb a tree."

It seemed like a cryptic statement, but to anyone who knew Paishon and his history, it made perfect sense: Few surfers on the West

Riding the Waves

For centuries Hawaiians of all social classes participated in he'e nalu, *or wave sliding, a sport with social and ritual importance. Modern surfers use boards made from synthetic materials that echo earlier wooden shapes.*



① Paipo/Bodyboard

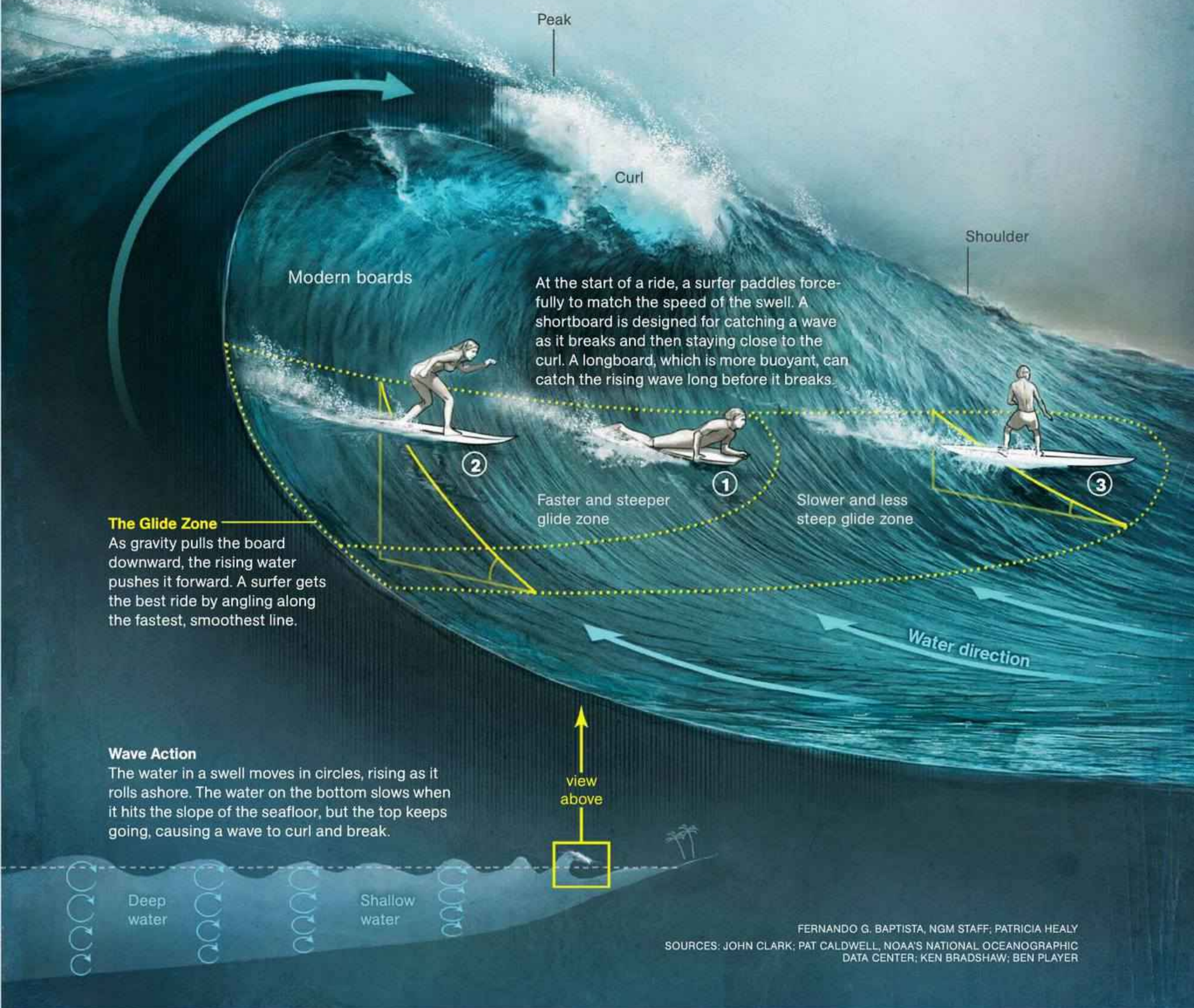
Long ago women and children rode these boards, paddling with their arms and kicking to catch a wave. Today the use of swim fins increases the force of the kick.

② Alaia/Shortboard

Ancient surfers used these boards on steep, fast-breaking waves. The modern curved profile improves maneuverability, aided by fins on the underside of the tail.

③ Olo/Longboard

Reserved for chiefs in the old days, the biggest boards are good for riding long, rolling waves. Under the right conditions, a surfer can glide for about 400 yards.



FERNANDO G. BAPTISTA, NGM STAFF; PATRICIA HEALY

SOURCES: JOHN CLARK; PAT CALDWELL, NOAA'S NATIONAL OCEANOGRAPHIC DATA CENTER; KEN BRADSHAW; BEN PLAYER

Moroni Naho'oikaika, a musician who lives near Makaha, hikes south of Kaena Point with his son Ezekiel. He wears tattoos of things that are close to his heart: the outline of Hawaii, footprints of an older son, a shark for protection, and verse that speaks to his faith. "Jah is God," he says. "God's word is the music."

Side have shown as much talent in the water while struggling against such long odds on land. There are obvious parallels between Paishon's story and Buffalo Keaulana's. Both were raised amid poverty and homelessness, and both found their calling in the ocean. But while Keaulana parlayed his waterman's talents into fame and a comfortable living, Paishon struggles to find his place in the world, dreaming of a career in pro surfing but with no obvious path to get there. You had to worry about his future.

Like many on the West Side, Paishon has an ambiguous ethnic heritage. His mother, Sharon, is a haole from New Jersey. His pidgin-speaking father, Don, is descended from Portuguese immigrants who came to the islands more than a century ago—along with Chinese, Japanese, and Filipinos—to work on sugarcane plantations. The line between native and non-native has long since blurred, and Don Paishon assumes that he and his son carry traces of Hawaiian blood, though he cannot say for sure. Even so, when I asked Sheldon whether he considers himself Hawaiian, he nodded emphatically. "In here," he

said, tapping himself on the chest. "In the heart."

But as Paishon takes pride in his Hawaiian identity, he faces many of the challenges that afflict the native population—especially on the West Side, one of the state's most disadvantaged communities.

When he was 12, his unemployed parents could no longer afford their apartment. For the next several years, the family lived in a tent just north of Makaha in what was then one of Hawaii's largest homeless encampments. Sharon struggled with depression, and Don smoked "ice," the popular name for methamphetamine. ("I like the rev and the high," Don told me.)

For their child it was sheer misery, an extended camping trip from hell. "Horrible, stinky, rainy, cold, scary," Paishon recalled. "Big centipedes crawling in your tent. Sand all over your bed. It's not what people think." A bucket served as the toilet, and a typical dinner was pork and beans heated over an open fire.

Like Keaulana before him, Paishon found solace in the ocean, graduating from a bodyboard to a succession of borrowed or discarded surfboards. He was a natural at the sport, and it wasn't long before he caught the eye of the uncles. They supported him with more surfboards (Paishon's aggressive style means that he breaks them on a regular basis) as well as food, clothing, and advice—a modern twist on Hawaii's ancient *hānai* system, in which families informally adopted the children of friends or relatives and raised them as their own. "We his real family over here," one of the uncles told me.

The line between native and non-native has long since blurred.

By the time Paishon was in his early teens, he was a regular on Oahu's highly competitive junior surfing circuit. His rivals turned up at events with their parents, equipped with beach canopies, video cameras, coolers, and surfboards plastered with logos from sponsors. Paishon had no sponsors and was lucky if his mom showed up with a beach towel. But that didn't stop him from winning, sometimes against kids who have gone on to lucrative professional careers. At 15, he was featured in *Surfing* magazine.

It was a different story at school, where Paishon struggled with basic math and reading and was mocked by his classmates for his mildewed clothes. "Everyone would tease me because they knew I was homeless," he said. "They called me the slum-dog surfer." He began

Keone Nunes tattoos Napu Hamasaki the old-fashioned way, by tapping on a sharp comb dipped in ink. This was a lost art for more than a century in Hawaii. “I was taught by a Samoan,” Nunes says, “the best traditional tattooist of his time.”

Ha‘a Keaulana prepares for one of the worst surfing mishaps—a wipeout that would hold her underwater—by running on the ocean floor while carrying a rock and pulling her friends. Her father, Brian, pioneered this technique to train lifeguards.

skipping school to surf. When he did show up, teachers yelled at him for reading surfing magazines in class. He dropped out entirely during his second attempt at completing the ninth grade.

People who knew Paishon were sympathetic to his plight, but there was only so much they could do. A couple whose son competed with Paishon on the junior circuit offered to take him into their home and pay his way to surfing contests in California and elsewhere, but Paishon's mother declined to sign a power of attorney form. "Maybe it would have been better," Paishon told me. "I would be a world champion by now, probably."

Some wounds were self-inflicted. Paishon admits he ran with the wrong crowd and smoked

"The bottom line is respect. You respect, you come surf anytime." —Bruce DeSoto

pakalolo—marijuana—sometimes paying for the drug by selling one of the surfboards he had been given. Benefactors began to lose patience. "I slapped his head," one of the uncles told me. "I told him, 'You're wasted talent, another wasted talent on the Waianae side, another lost soul.'"

The biggest setback came when Paishon was accused of stealing $1,200 from the girlfriend of a contest organizer. Paishon was never charged, but his reputation was damaged. Potential sponsors turned away. "They think, He's a punk, he's from Waianae," Paishon said bitterly.

One late-spring night I drove with him past Waianae High School, where the commencement ceremony for the class of 2013—Paishon's class, had he stayed in school—had just concluded. Paishon watched silently as joyful graduates spilled into the street with their parents and siblings. Several minutes passed. Finally he said, "I wish I would have graduated."

Six months later I learned that Paishon had found a job. A friend had hired him to clean cars for eight dollars an hour. "Everyone is looking at me different now because I'm working," he told me. "It's my step forward." He said he planned to use his earnings to finance a surfing trip to Indonesia and then return to Hawaii for a new round of contests that he hoped would win the attention of sponsors. "I didn't know what I wanted before," he said. "Now I know. Be a pro surfer. That's my dream."

AFTER MY INITIAL surfing misadventure at Makaha, I went to see Bruce DeSoto, a member of one of Makaha's most prominent families.

Surfers cross busy Kalakaua Avenue after a day of riding the long, gentle waves that roll into Waikiki Beach. Upscale stores, luxury condos, and grand hotels now line the shore in this neighborhood, but passages between the buildings allow public access to a stretch of sand and surf that's popular with locals as well as tourists.

I asked him for advice on avoiding any further unpleasantness in the water. He leaned back in his armchair and replied, "When somebody new comes in the lineup, we expect them to introduce themselves and say hi, at least." He continued, "The bottom line is respect. You respect, you're welcome, then you come surf our place anytime you want. But if you don't respect, then you got a problem."

A few days later I got a chance to put his advice into practice. A fresh swell had rolled in, and the waves were bigger than I'd seen them. I paddled out and struck up a conversation with a stocky Hawaiian in his early 40s. It turned out he was a lifeguard in Makaha who shaped surfboards on the side. Bobbing on one of his own creations, he told me proudly about his three kids and their plans to compete in a weekend surfing contest in Honolulu.

Then we both spotted a peak. I looked at him. Mine? His nod was subtle to the point of telepathy. I paddled hard and dropped in on the wave, a glorious, eight-foot wall of cobalt blue that carried me past the reef. □

Just after dawn two sisters and their cousin head into the surf at Makaha to warm up before a competition. Participating from an early age in this ancient sport of Hawaiian chiefs teaches children to take pride in the culture they've inherited.

They hide in your bed and breed on your face. They're smaller than the period at the end of this sentence. They are...

Mighty Mites

Magnified hundreds of times, this predatory soil mite is the terror of its microscopic world.

PARAZERCON SP., MAGNIFIED 556 TIMES

By Rob Dunn

Photographs by Martin Oeggerli

Several years ago I made a bet about face mites, animals that live in hair follicles. They are so small that a dozen of them could dance on the head of a pin. They are more likely, though, to dance on your face, which they do at night when they mate, before crawling back into your follicles by day to eat. In those caves mother mites give birth to a few relatively large mite-shaped eggs. The eggs hatch, and then, like all mites, the babies go through molts in which they shed their external skeleton and emerge slightly larger. Once they're full size, their entire adult life lasts only a few weeks. Death comes at the precise moment when the mites, lacking an anus, fill up with feces, die, and decompose on your head.

Currently two species of face mites are known; at least one of them appear to be present on all adult humans. My bet was that even a modest sampling of adults would turn up more species of these mites, ones that are totally new to science.

Biologists often make bets; they call them predictions to sound fancier. My bet was based on an understanding of the tendencies of evolution and of humans. Evolution tends to engender its greatest richness in small forms. Humans, on the other hand, tend to ignore small things. Aquatic mites, for example, live in most lakes, ponds, and even puddles, often in densities of hundreds or thousands per cubic meter. They can even be found in drinking water, yet few people have ever heard of aquatic mites, including, until recently, me. And I study tiny things for a living.

Mites also live in dust, where they have found unwelcome fame by eating the bits of dead skin that trail behind us everyplace we go. Our shadows of shed life sustain multitudes.

Some of the real monsters of the mite world live in soil, where one can find predatory mites armed with a medieval arsenal of mouthparts. Some have jaws with sharklike teeth; others bear smooth blades that snap together with tremendous force; still others stab with sharp and deadly sabers. These beasts stalk the tunnels of worms and the tiny holes between grains of sand.

Other mites live in rain forest canopies, on leaves and in the soil that accumulates in the nooks and crannies where branches meet trunks, and in the cups of epiphytic plants.

Even some of our food is mity. The flavor of Mimolette cheese comes from their tunneling, eating, excreting, and coupling. In fact, it's no exaggeration to say that mites alter the world. They can make soil turn over faster or slower, decomposition speed up or slow down, crops grow sick or healthy. Their little limbs punch far above their weight.

Just how many species of mites exist in the world today is not well understood. Probably

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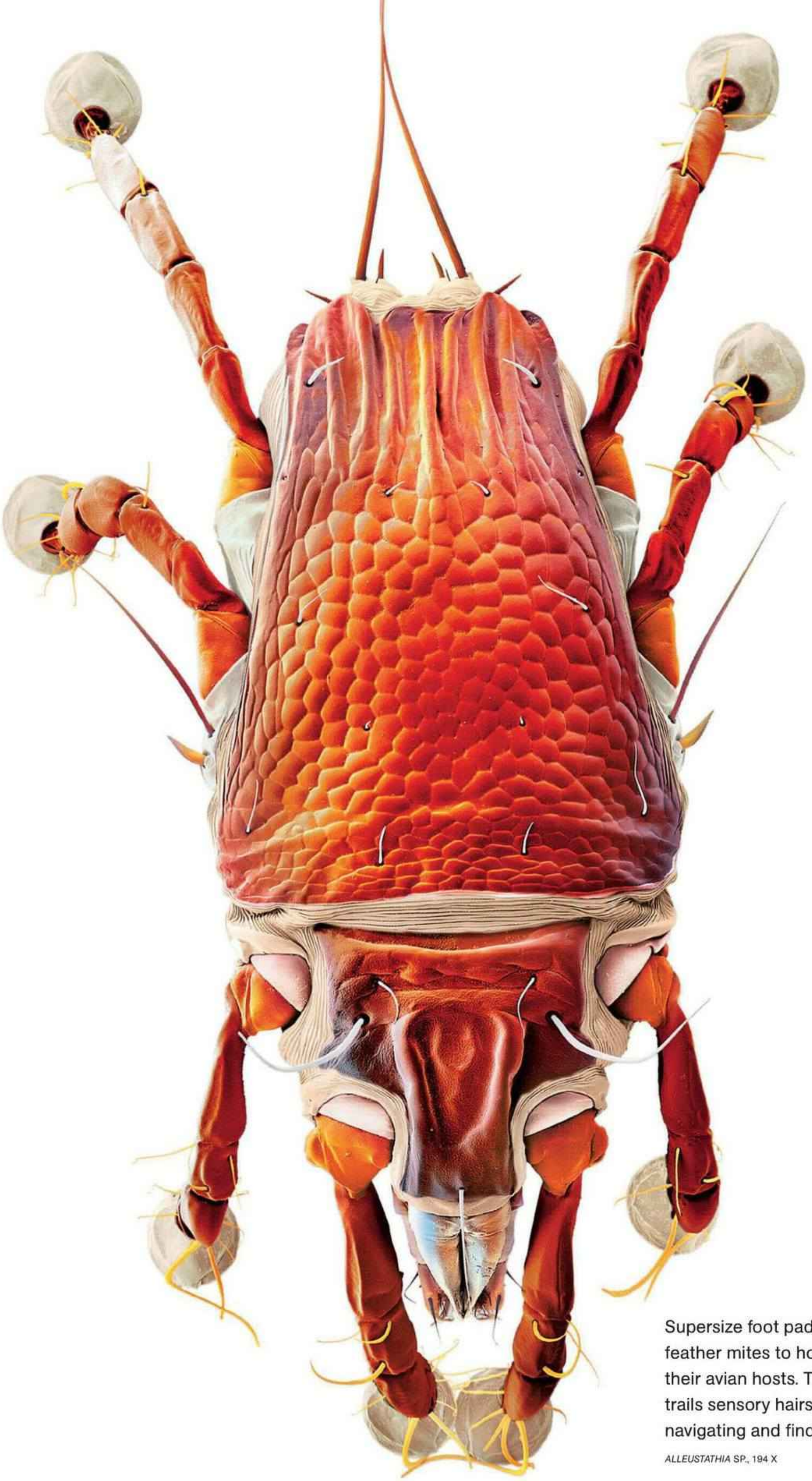
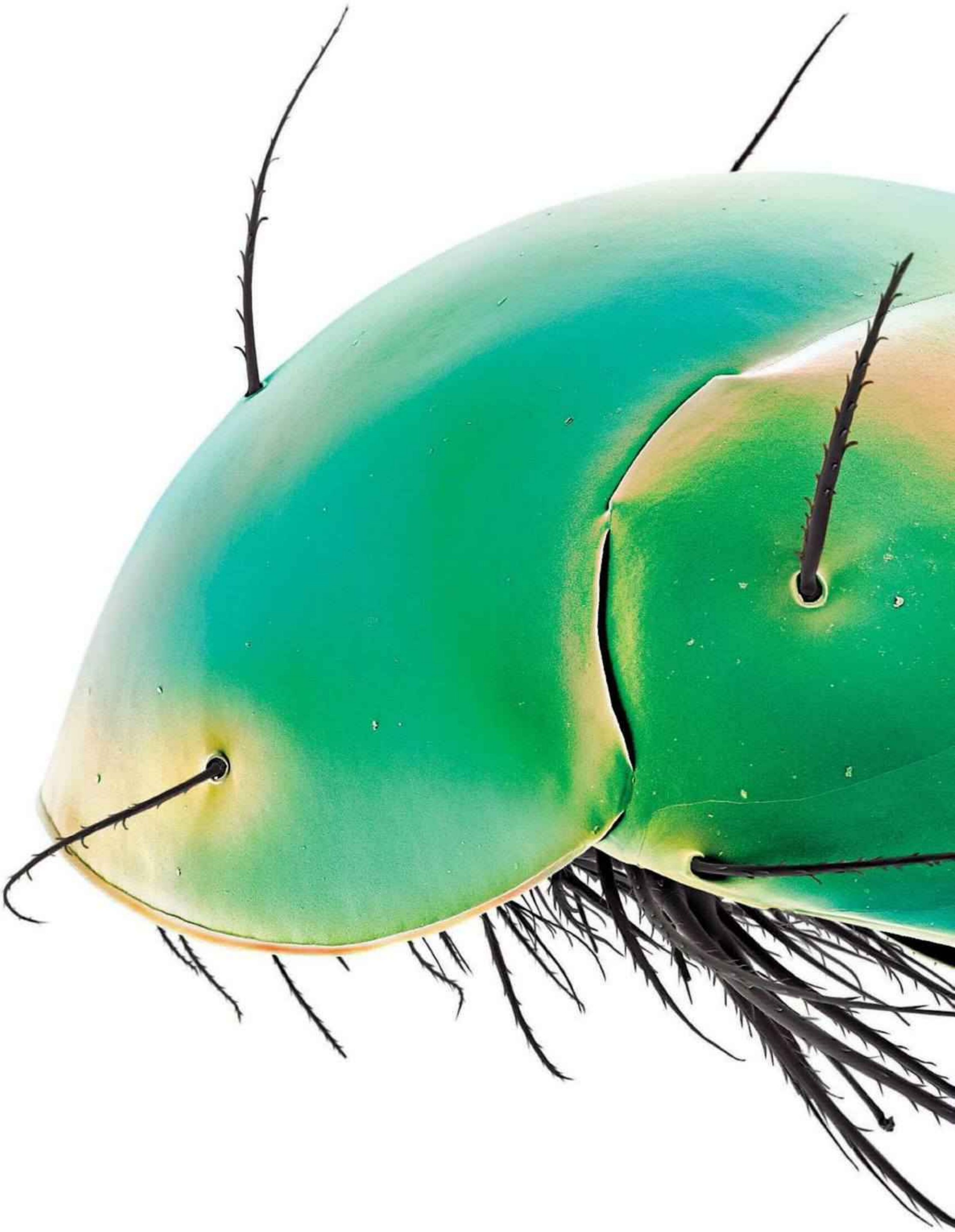
Rob Dunn is an evolutionary biologist at North Carolina State University. Swiss photographer Martin Oeggerli specializes in scientific microscopy.

ALL PHOTOGRAPHS MADE WITH SUPPORT FROM SCHOOL OF LIFE SCIENCES FHNW, SWITZERLAND.
SOURCES: HEATHER PROCTOR, UNIVERSITY OF ALBERTA, CANADA; ELKE MCCULLOUGH, UNIVERSITY OF GRAZ, AUSTRIA



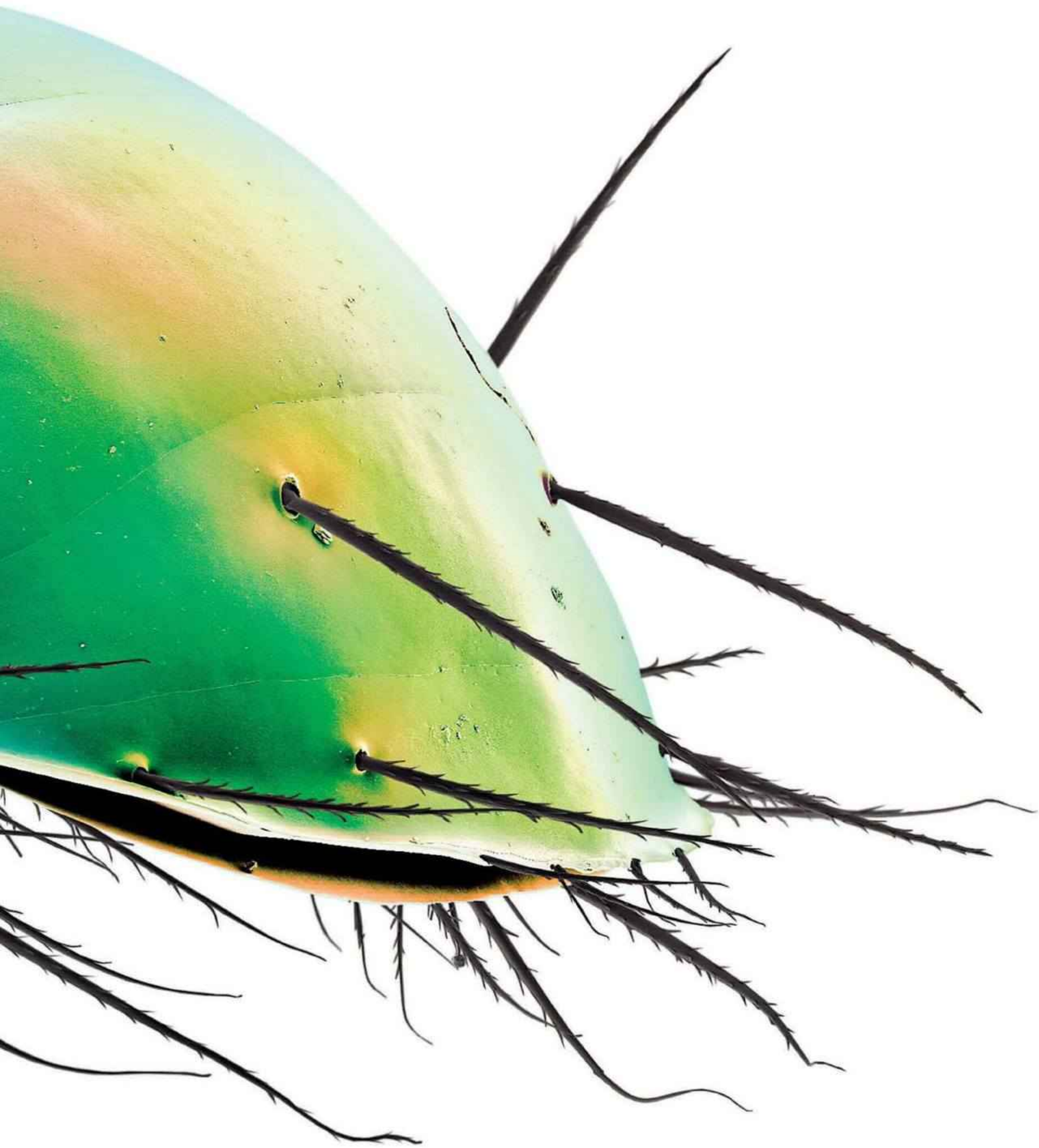
Supersize foot pads enable feather mites to hold fast to their avian hosts. This species trails sensory hairs, used for navigating and finding mates.

ALLEUSTATHIA SP., 194 X



Heavily armored scutacarid mites hitch rides on larger arthropods (including other mites) in their search for food, tumbling off when they arrive at a source of fresh fungi and other microbes.

SCUTACARIDAE, 629 X



The eating end of an oribatid soil mite is equipped with "more tools than a Swiss army knife," says photographer Martin Oeggerli. They include short pincerlike appendages and tiny limbs for handling food.

HERMANNIELLA SP., 1,500 X

at least a million, but no one knows enough to say with confidence, nor will anyone know for decades. Museum collections are filled with mite species no one has yet had a chance to study. Some undoubtedly offer fascinating evolutionary stories. Others eat herbivorous insects and could benefit agriculture or medicine. Still others may be vectors for deadly pathogens.

Another reason for my bet: Mites are specialists that occupy every conceivable niche, including the trachea of bees, the shafts of feathers, the anuses of turtles, the stink glands of bugs, the digestive systems of sea urchins, the lungs of snakes, the fat of pigeons, the eyeballs of fruit bats, the fur around vampire bat penises. Living in these habitats necessitates special hairs, chemicals, foot pads, mouthparts, and tricks. It also requires a way to get from one patch of good habitat to the next.

Some mites ride from flower to flower in the nostrils of hummingbirds. When the bird hovers at a flower, the mite sniffs the blossom to see if it's the right kind for finding a mate among the petals. If it is, the mite runs down the bird's beak at speeds that are, in terms of body lengths traveled, some of the fastest on Earth.

Other mites hitch rides on the backs of beetles or ants; some fly in the ears of moths. One species of mite hangs on to the hind foot of the army ant *Eciton dulcius,* and its hind legs serve as surrogates for the ant's own claw. Others float through the clouds or on loops of silk that they produce and unfurl into the wind.

All of this is to say that if one can imagine a habitat, however narrow, mites are there, even if that habitat is hard to reach on legs just microns long and a tenth the thickness of a human hair.

Yet the marvels of mite transport pale in comparison with the idiosyncrasies of mite reproduction. Some clone themselves. Others eat their mothers. Others mate with their sisters while still inside their mothers and then, during birth, kill their mothers. In the nostrils of hummingbirds and the ears of moths lurk Greek tragedies of small, strange lives.

The habitats that offer mites the most advantages are bodies, whether of mammals, birds, insects, or any other creature larger than a mite. Bodies are the buffet bus of life, providing food and transportation. Mites that live on bodies are specially adapted to hold fast to their host, even when it runs, swims, or flies.

Most bird species host more than one specialized mite found nowhere else. One species of parakeet has 25 different species of mites living on its body and in its feathers, each in a different microhabitat. Rabbits host several species of mites, mice as many as six. Even seals have their own mites.

Given such diversity and specialization, it's easy to imagine that a roomful of people (think of all the habitats!) would be fertile ground for discovering mites—and for making good on my bet. For a long time this was just a conversation starter at slow parties. But recently some collaborators and I gathered a group of folks and asked them to sample their own skin. After some swabbing, poking, and DNA sequencing, we found mites on every adult we sampled, including one species new to science that seems to live mainly on people of Asian descent. Think of it: A mite that probably lives on millions of humans, maybe even billions, and yet it was totally unknown until that moment. I was thrilled.

How did mite systematists—scientists who name new species—respond? A few were excited; the rest shrugged. They knew that my bet for mite diversity was an easy one, a fact of life they witness every time they examine a scoop of soil, peer into moss, or swab a friend. In fact, one need look no farther than the mites pictured in this article, most of which are unnamed species. In all likelihood they will long remain that way, mysteries in plain view, like most of life. □

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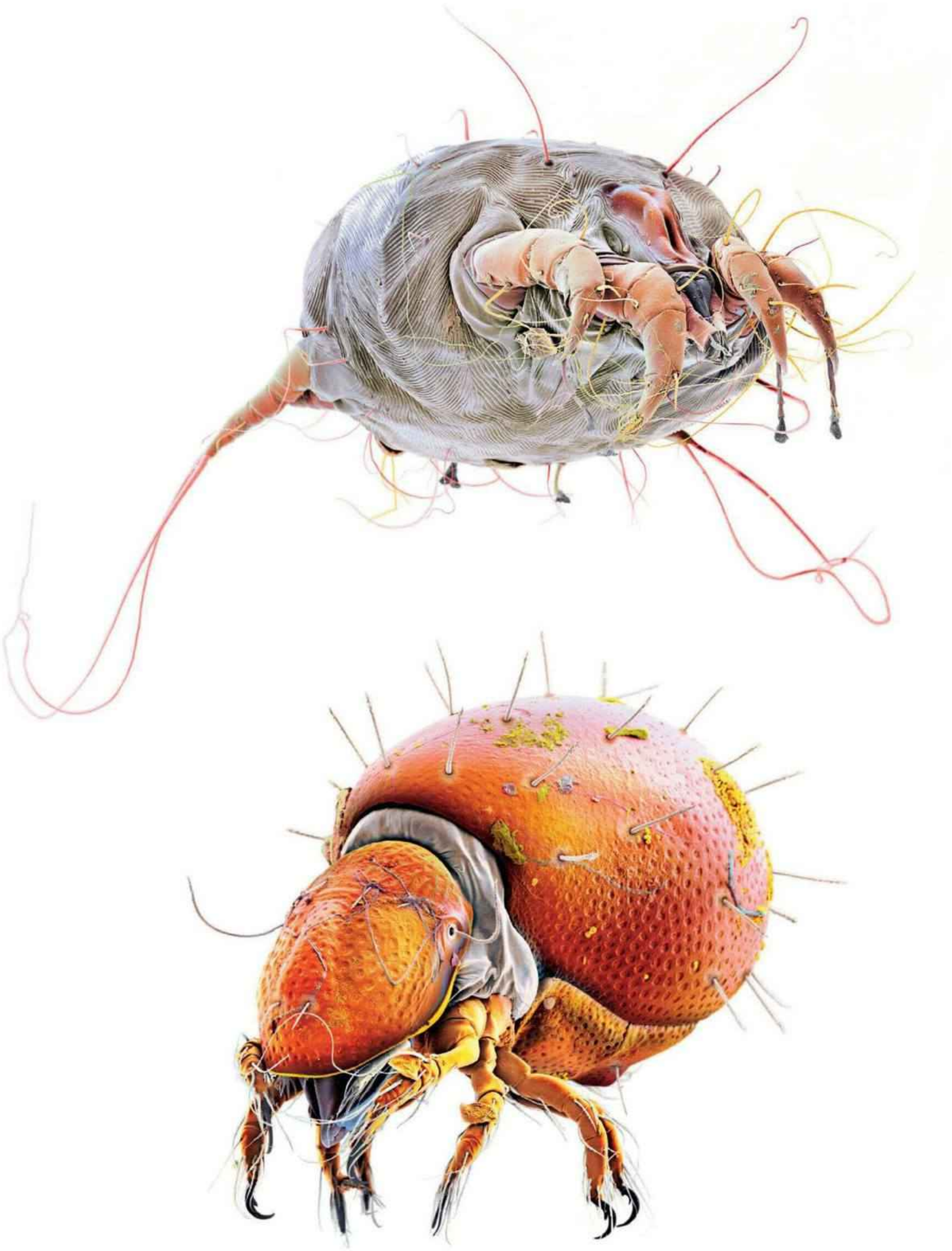
INTERVIEW

A Scientist and His Art

Photographer Martin Oeggerli talks about how he creates and colors his images and why he refers to himself as a "micronaut"—an astronaut for the microcosmos.

VIDEO



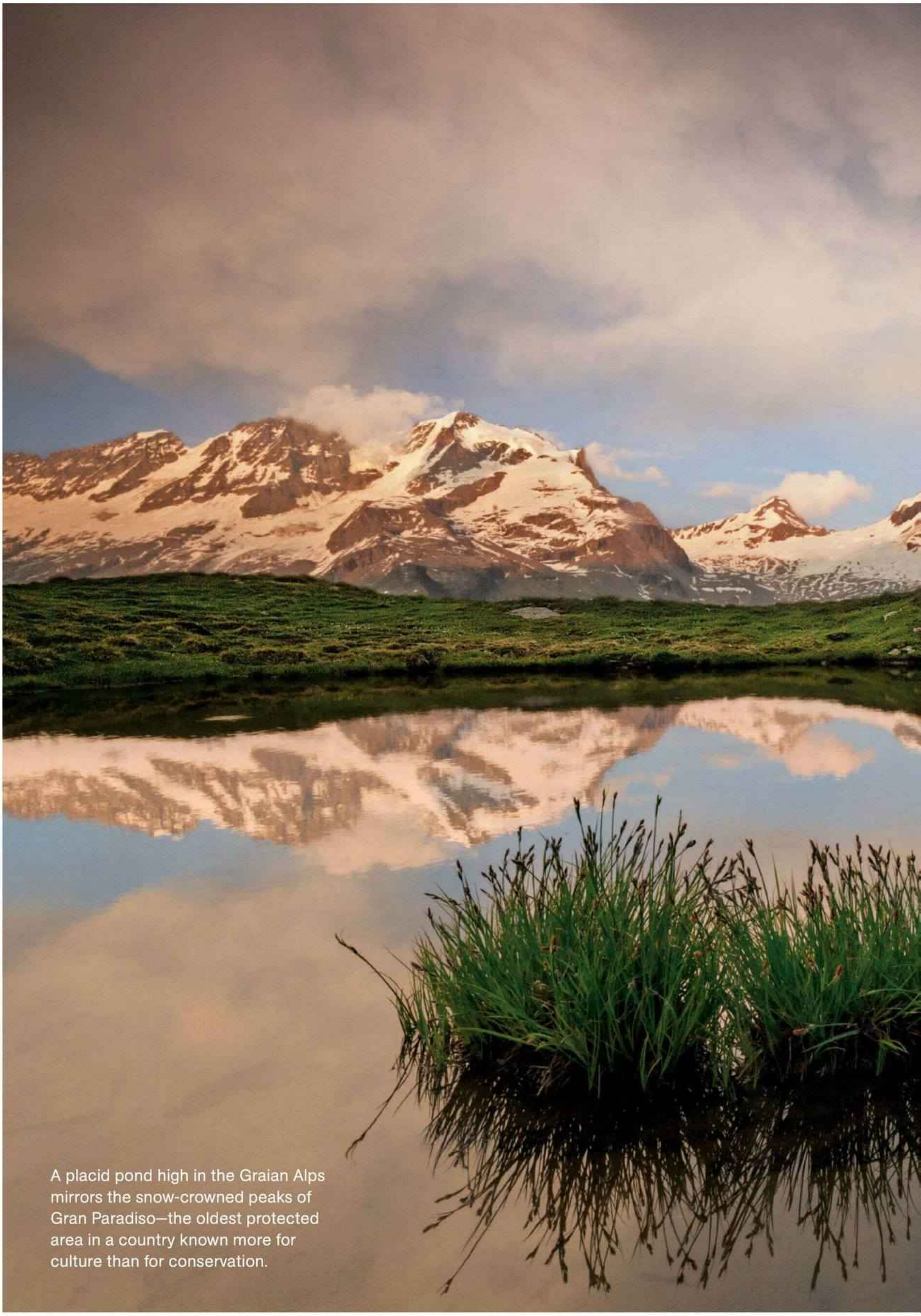
Rabbit ear mites (top) chew on their unwitting host. The rabbit scratches, its ear oozes, and the mite feasts on the fluid. Box mites (above) retract their limbs and snap shut when threatened.

PSOROPTES CUNICULI (TOP), 428 X; *ATROPACARUS STRICULUS*, 262 X

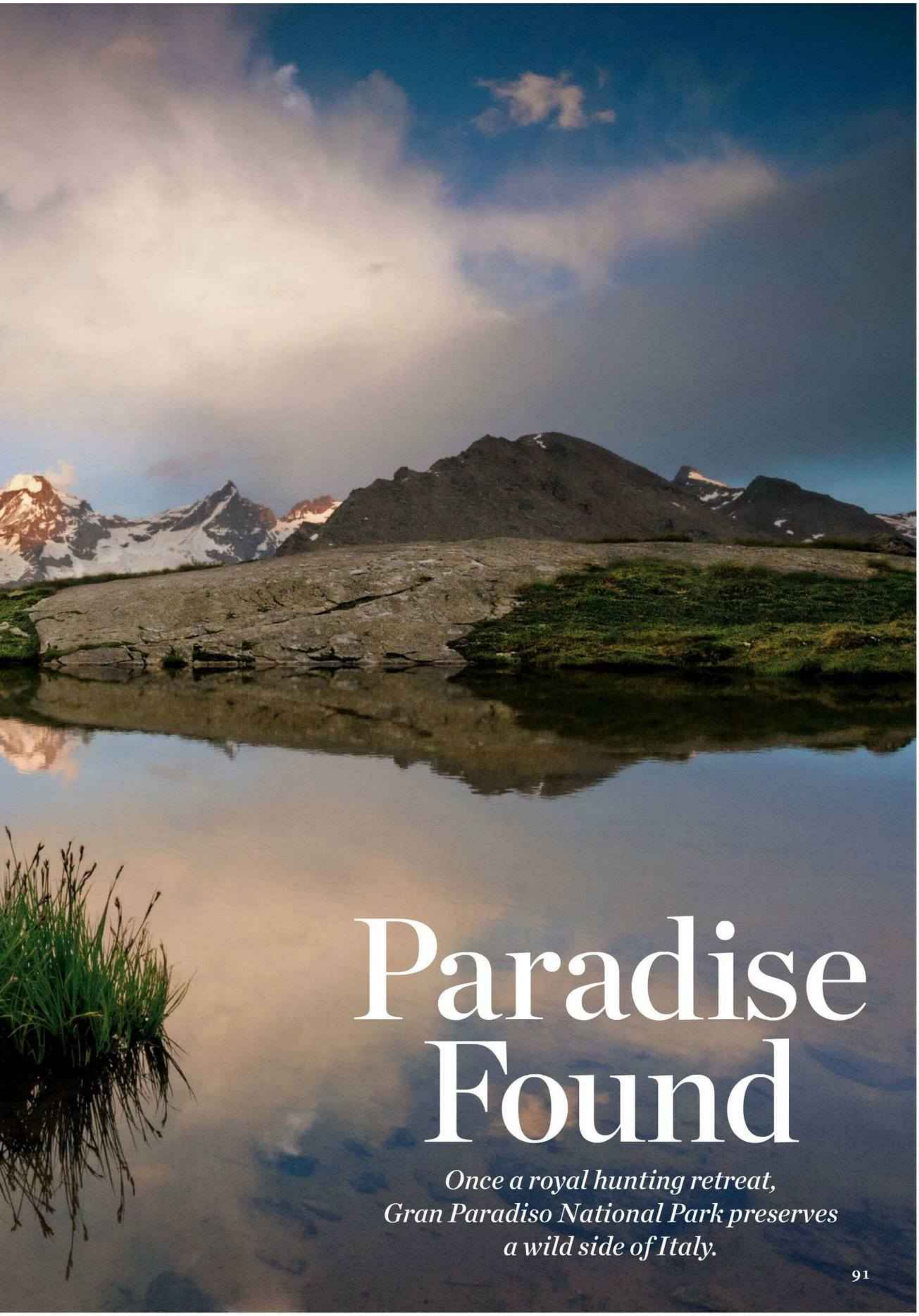
Scientists are discovering that mites are exquisitely adapted to nature's every niche. Case in point: Colorful beads of water-repellent wax ensure that a moss mite stays dry in its damp world.

EOBRACHYCHTHONIUS SP., 996 X

The photographs in this article were made with a scanning electron microscope.
The resulting black-and-white images were then colored to reflect the mites' natural appearance.



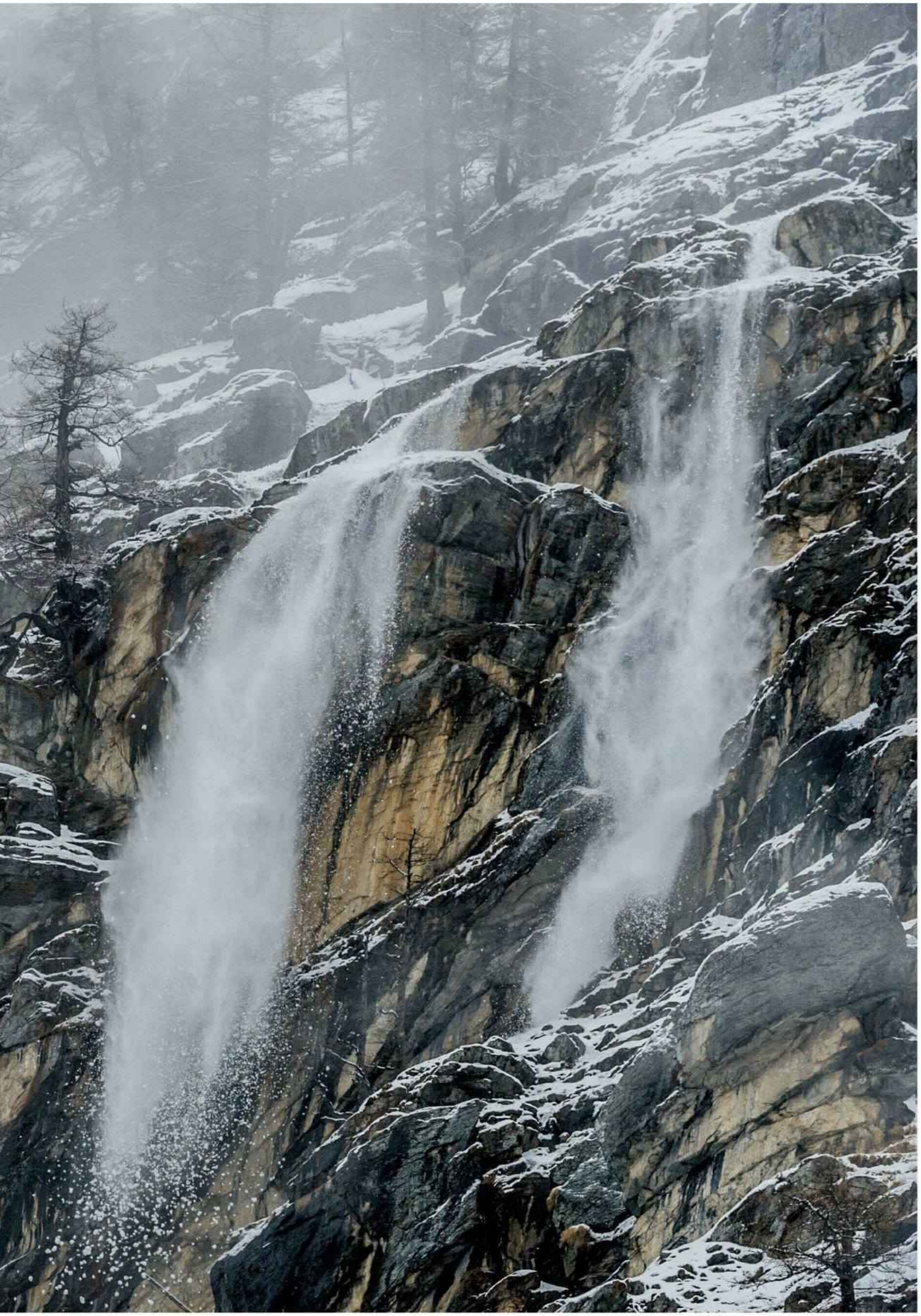
A placid pond high in the Graian Alps mirrors the snow-crowned peaks of Gran Paradiso—the oldest protected area in a country known more for culture than for conservation.



Paradise Found

Once a royal hunting retreat, Gran Paradiso National Park preserves a wild side of Italy.

Late winter snow cascades down the rocky slopes of Valsavarenche valley. Ruinous avalanches are rare in Gran Paradiso, but in 2008 one destroyed several houses in two park villages.



By Jeremy Berlin
Photographs by Stefano Unterthiner

On a crisp summer morning in Degioz, a slate-roofed village in northern Italy, Luigino Jocollè is sharing the local news. He and four other gray-haired men are sitting in a tiny café, sipping cappuccino as espresso machines whir and pastry sugar perfumes the air. But they're not discussing sports or politics.

"Three nests!" exclaims Jocollè. His friends murmur and nod. "Three nests in a single kilometer! Extraordinary."

They're talking about their neighbors. A pair of bearded vultures—breeding again in the wild a hundred years after the last one vanished from the Alps—has taken up residence near two pairs of golden eagles. The return of a majestic species, and the sight of two top predators living so close together, might be cheered in many places. But in Gran Paradiso National Park, where wilderness and culture live in careful balance, it's a matter of daily consequence.

Gran Paradiso is Italy's oldest national park. Established in 1922, it's tiny by American standards: 274 square miles in the Graian Alps, straddling the Piedmont and Aosta Valley regions in the country's rugged northwestern corner. But taken together with France's adjoining Vanoise National Park, it's one of the largest protected areas in Western Europe.

Drive an hour from Turin and you'll know when you've arrived. Highways become switchbacks climbing steeply into *Sound of Music* country—snowcapped mountains, alpine meadows, larch-forested valleys carved by rivers and glaciers. The sound of water is constant. The scent of pine is everywhere. In the heart of civilized Europe, the park Italians call "big heaven" blooms like an earthly Eden. No wonder the past two popes vacationed here.

But human hands have shaped the landscape too, leaving fingerprints old and new: Neolithic rock etchings, Roman ruins and medieval castles, solar panels and hydroelectric dams. Since World War II many people have left the area for jobs in cities. Yet some 8,400 still live in the park's 13 municipalities, sharing space with more than 50 species of mammals, a hundred kinds of birds, and nearly a thousand types of plants and flowers. Plus 1.8 million tourists a year.

Dominated by its namesake 13,324-foot-tall massif, Gran Paradiso today is a high-altitude hub of wildlife conservation, scientific research, and cultural preservation. But its ironic story begins in the 19th century. And it starts with a mountain goat.

"IF THERE WERE NO IBEX," says Pietro Passerin d'Entrèves, "there would be no Gran Paradiso."

The Turin University zoology professor is a historian of the region, where his family has lived since 1270. On a cloudy day in Cogne, the park's unofficial capital, he tucks into a plate of gnocchi and unpacks the past.

From the 16th century to the 19th, he says, alpine ibex were hunted for their meat, horns, blood (said to boost virility), and a bone from

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Jeremy Berlin is a staff writer for the magazine. Photographer Stefano Unterthiner lives near Gran Paradiso. He'll publish a book on the park this year.

Flanked by his retinue, Italy's King Victor Emmanuel II (seated) takes a break during an ibex hunt around 1869. Before 1922, when it became a national park, this area was the king's exclusive hunting ground.

which the superstitious made amulets. By 1821 fewer than 50 were left. So in 1856, after one protective measure had failed, Victor Emmanuel II set aside a royal reserve to save the species—for himself. The Savoy king loved to hunt, and the graceful ibex were his favorite quarry.

Soon paths were cleared, lodges built, villages absorbed into the new territory. Hunters and poachers were hired as game wardens. And locals were paid to organize the king's annual hunt.

By 1900, when Victor Emmanuel III took the throne, the ibex population had swelled to 2,000. But as war engulfed Europe, the new king was too busy to hunt. So in 1920 he turned the hunting preserve into a true sanctuary, which he donated to the state. Two years later the area was granted national park status.

The park's creation has led to state-landowner squabbles, but ibex poaching is no longer an issue: There have been just a handful of reported cases in the past ten years. That's because the local economy is vested in ecotourism—and because the park assigns 58 wardens to patrol 175,553 acres spread over five valleys.

As the sun burns off the last tatters of morning cloud, one of those wardens climbs an old hunting path from the pine-thick Valsavarenche valley to the boulder-strewn Nivolet Plateau. A hulking man with a mournful face, Giovanni Bracotto pauses at the pass to point out stone ruins of cattle barns dotting the slopes and pastures that sit above a tumble of scree.

"A hundred years ago," he says, "the economy here was agricultural. The grass had more nutrients then, so the milk was better. The summer cheese was too. But many things have changed."

Including the wardens' jobs. Working alone from dawn to dusk—14 hours in summer—they repair trails, assist hikers, and monitor the park's 59 (shrinking) glaciers. They also keep tabs on

PHOTO: LUIGI MONTABONE, PIETRO PASSERIN D'ENTRÈVES COLLECTION

A red fox lies in wait, camouflaged in the autumn woods. Like all foxes, those in Gran Paradiso are adaptable opportunists; they'll catch fish, hunt rabbits, or scavenge picnic scraps.

wildlife. Using GPS, computer tablets, telescopes, and thermographic cameras, Bracotto and his crew help the park's scientists tag, collar, and tally ibex and chamois, the park's other wild goat. Last September their ibex count—2,772—confirmed a 20-year trend: When it comes to the park's spirit animal, there's trouble in Gran Paradiso.

AS DUSK CLOAKS the Alps in shadow, Achaz von Hardenberg lowers his binoculars.

The park's fair-skinned, German-born biologist is standing on the rim of a peaceful valley called Levionaz, waiting to weigh ibex. Earlier, during the fine warm day, herds of four and five were loping elegantly across the plateau and grazing high on the cirque's slopes. But tonight they're ignoring the salt lick von Hardenberg has set up next to an electronic scale. "I don't know where they could be," he mutters.

indicated that ibex meat was part of his last meal.

"Yet after all this time they're still not well adapted to life up here," says von Hardenberg. "They were hunted in the lowlands during prehistoric times, which may have been what pushed them to the highlands. Over thousands of years they've adjusted to the harsh climate, but they still don't thrive in deep winter snow."

As the night wears on in Levionaz, the valley stirs. A marmot sips from a rushing stream. A fox finds a dead chamois in a crevasse and enjoys a hasty dinner. But ibex are nowhere to be seen.

IBEX ARE GRAN PARADISO'S raison d'être, but they aren't the only inhabitants of note.

In the gneiss hills above Nivolet, a researcher named Luca Corlatti is tracking chamois, less famous but more populous than ibex—latest count, about 8,000—with numbers remaining stable. On the green slopes of Orvieille, Caterina Ferrari is deciphering the personalities and social structures of marmots—furry, bearlike rodents that lumber comically through the tall grass, whistling coded warnings to each other. And on a raft in Lake Djouan, Rocco Tiberti has netted thousands of brook trout, removing a species that's gobbled up insects and other native organisms since it was imported in the 1960s.

Some call the wolves a monstrous threat to livestock. Others sell cute wolf T-shirts alongside prosciutto.

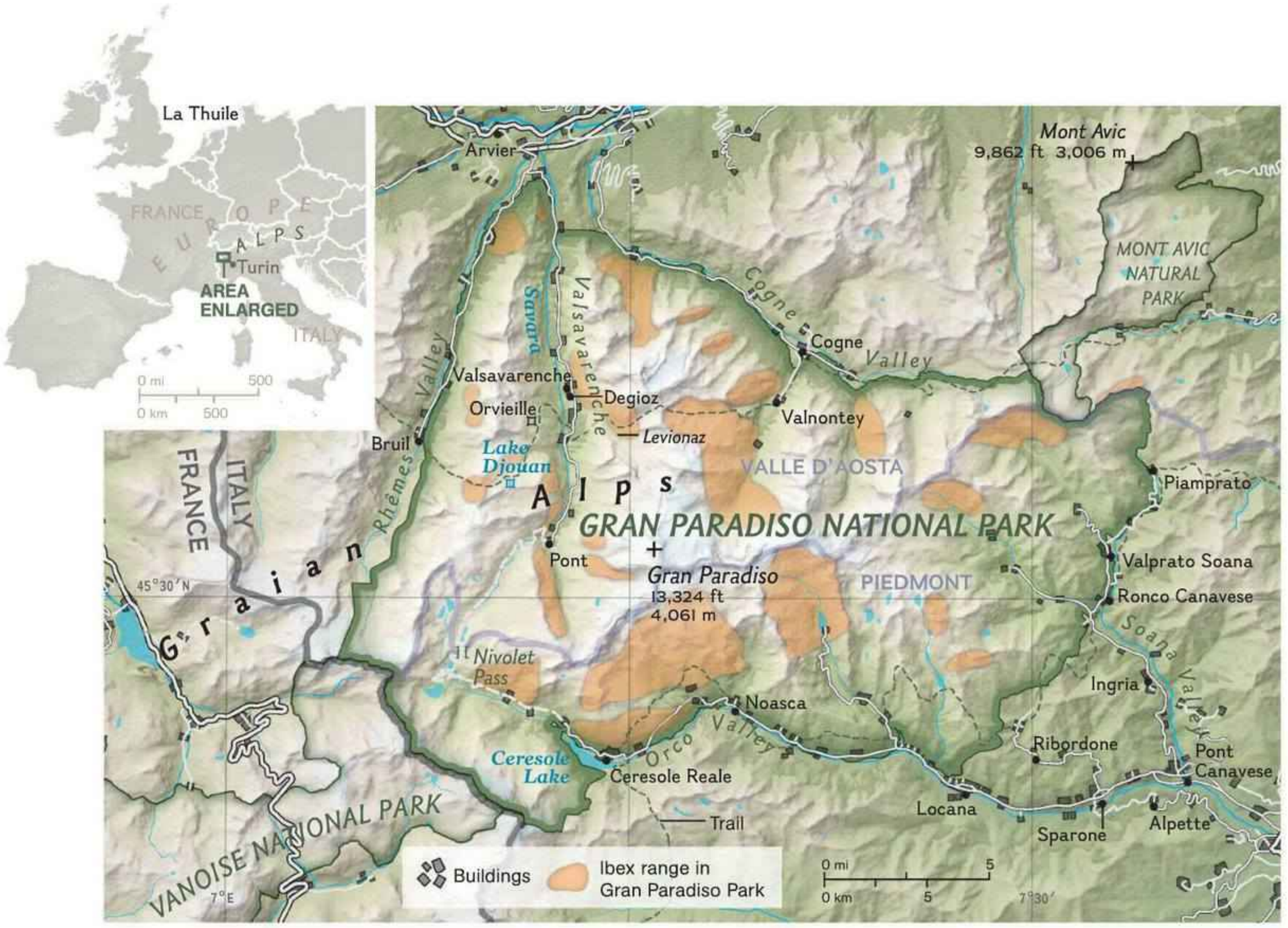
In 1993 you couldn't miss them: There were nearly 5,000 in the park, a high-water mark. Their numbers have been dwindling ever since.

No one is sure why, but theories abound. Von Hardenberg has two of his own. One is that older females are breeding now, producing weaker kids that are less equipped to thrive. His other theory is rooted in climate change: Grass used to peak here in high summer, when ibex kids are born. Now, because there's less snow, the grass grows earlier in the year. That means newborns have less to eat, less nutritious milk to drink—and less chance of living long enough to claim mates and have kids of their own.

Von Hardenberg is hoping an analysis of satellite data—showing how alpine-meadow vegetation has changed over three decades—will help solve the mystery. But ibex are an age-old puzzle, he says. In coastal Puglia, the heel of Italy's boot, fossil remains reveal the animals' ancient presence. So did the guts of Ötzi, the 5,300-year-old preserved mummy found in 1991; DNA analysis

Then there's the wolf. In 2007, more than a century after the species was exterminated here, a pack of seven appeared in Aosta Valley. When a few shepherds lost sheep, the wolves were blamed. In 2011 the pack vanished—"probably shot," says von Hardenberg—but the next year another pair arrived, this time in the lush Soana Valley. By last fall there were at least five again.

Bruno Bassano, the park's veterinarian and scientific manager, says the wolves are a boon: They cull foxes and wild boars, balancing the ecology. But locals are divided. Some call the animals a monstrous threat to their livestock.



Others monetize them. In a delicatessen in the village of Piamprato, T-shirts with cute wolf cartoons hang for sale alongside strips of prosciutto.

Anna Rotella is untroubled. On a bright July morning in Valsavarenche, she and her partner, Claudio Duguet, milk dozens of white sheep and goats, then lead the flock across the turbulent Savara River, where the grass is good. "Only the ignorant people fear the wolf," Rotella says. "Educated farmers and shepherds know it is not evil. It is just hungry, like anything else."

Over on the Piedmont side of the park, the ruddy-faced Longo family—Beppe, Lina, and their grown son, Claudio, plus his girlfriend, Licia—say the wolves don't bother them either. They live in a stone house with a leaning A-frame, ringed by emerald slopes veined with waterfalls and avalanche stains. Everything here is done by hand, as it was a hundred years ago. A cell phone is the only concession to modernity.

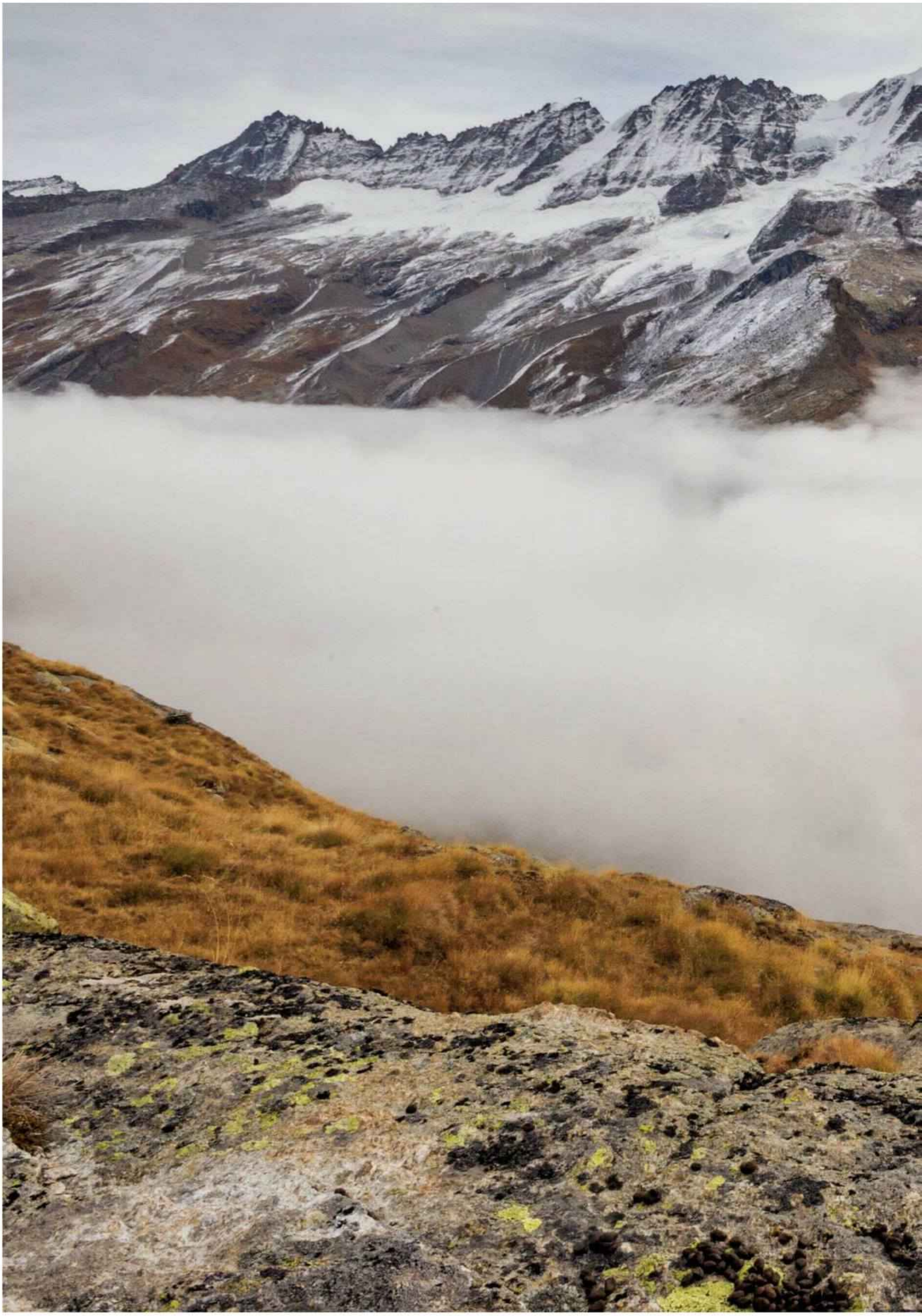
As chickens squawk and cowbells clonk, Beppe and Claudio pull six round blocks of cheese from a rusted iron cauldron boiling with freshly drawn milk. Lina scoops softball-size chunks of butter from an old churn, then pounds the yellow globs into a bricklike block. Licia washes clothes in a bathtub, using a scrub, a rock, and water delivered by a Rube Goldberg–esque sluice system that snakes up the hill.

About ten other families in the valley live similarly. It's a break-even existence: The profit they make from selling their dairy products at market covers rent and little else. But, says Lina, it's a lifestyle that's as priceless as it is timeless.

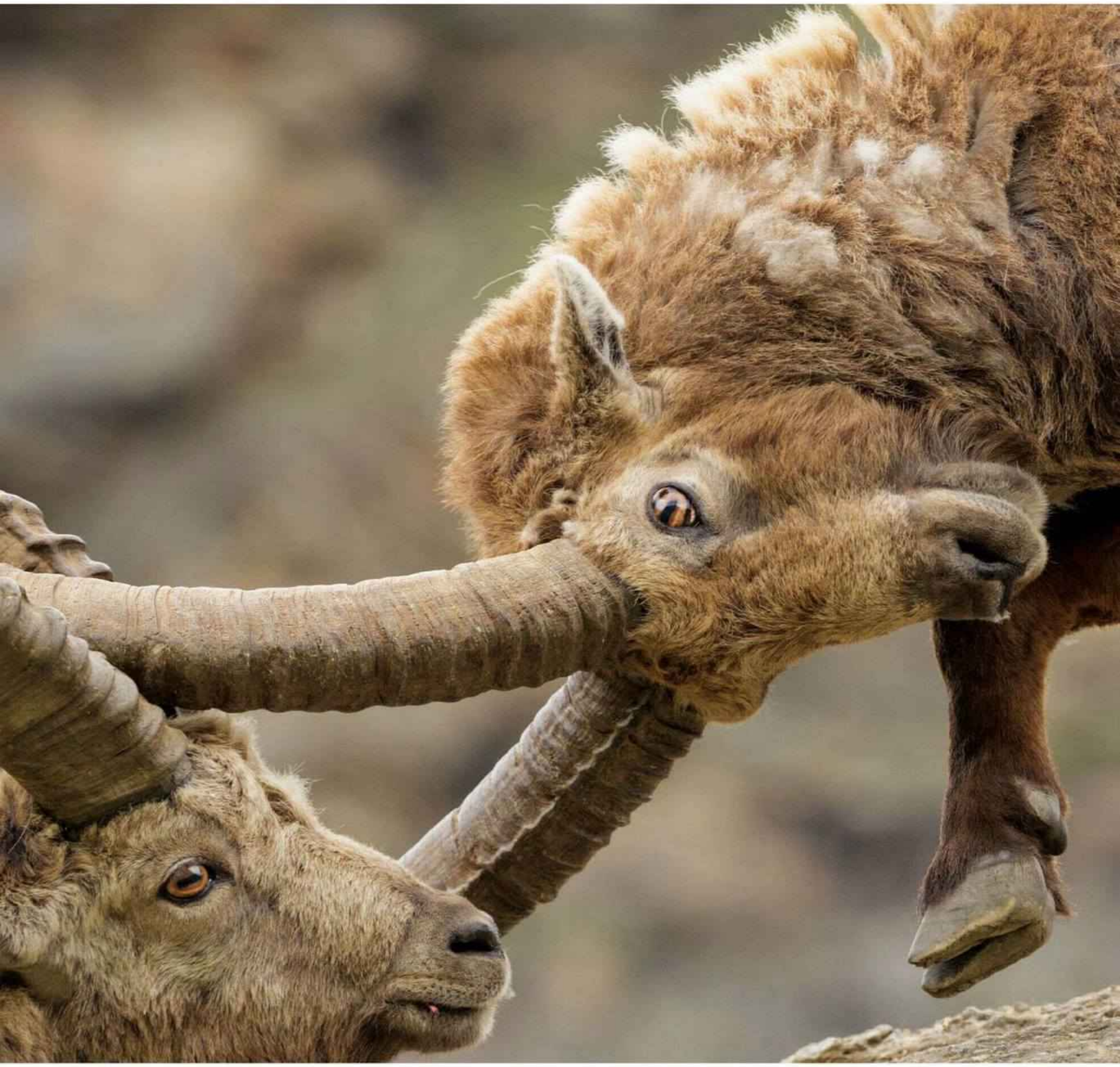
BACK AT THE CAFÉ IN DEGIOZ, Luigino Jocollè says there's not enough money for national parks these days, and too much bureaucracy. As environmental laws clash with building codes and business interests, it can be hard to maintain the park's unique blend of culture and conservation. Which is nothing new.

"In Gran Paradiso," says Jocollè, "we always have to balance social and natural priorities." □

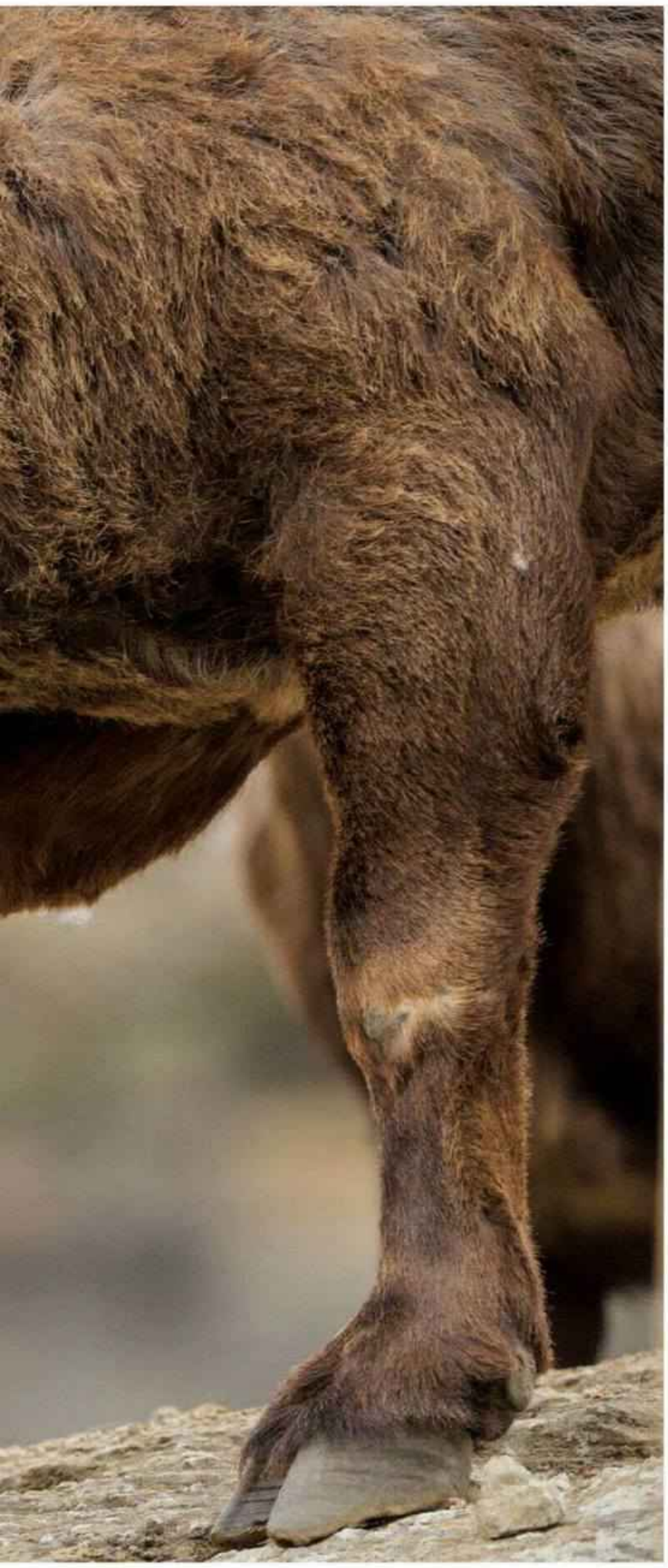
VIRGINIA W. MASON, NGM STAFF. SOURCE: GEO4MAP



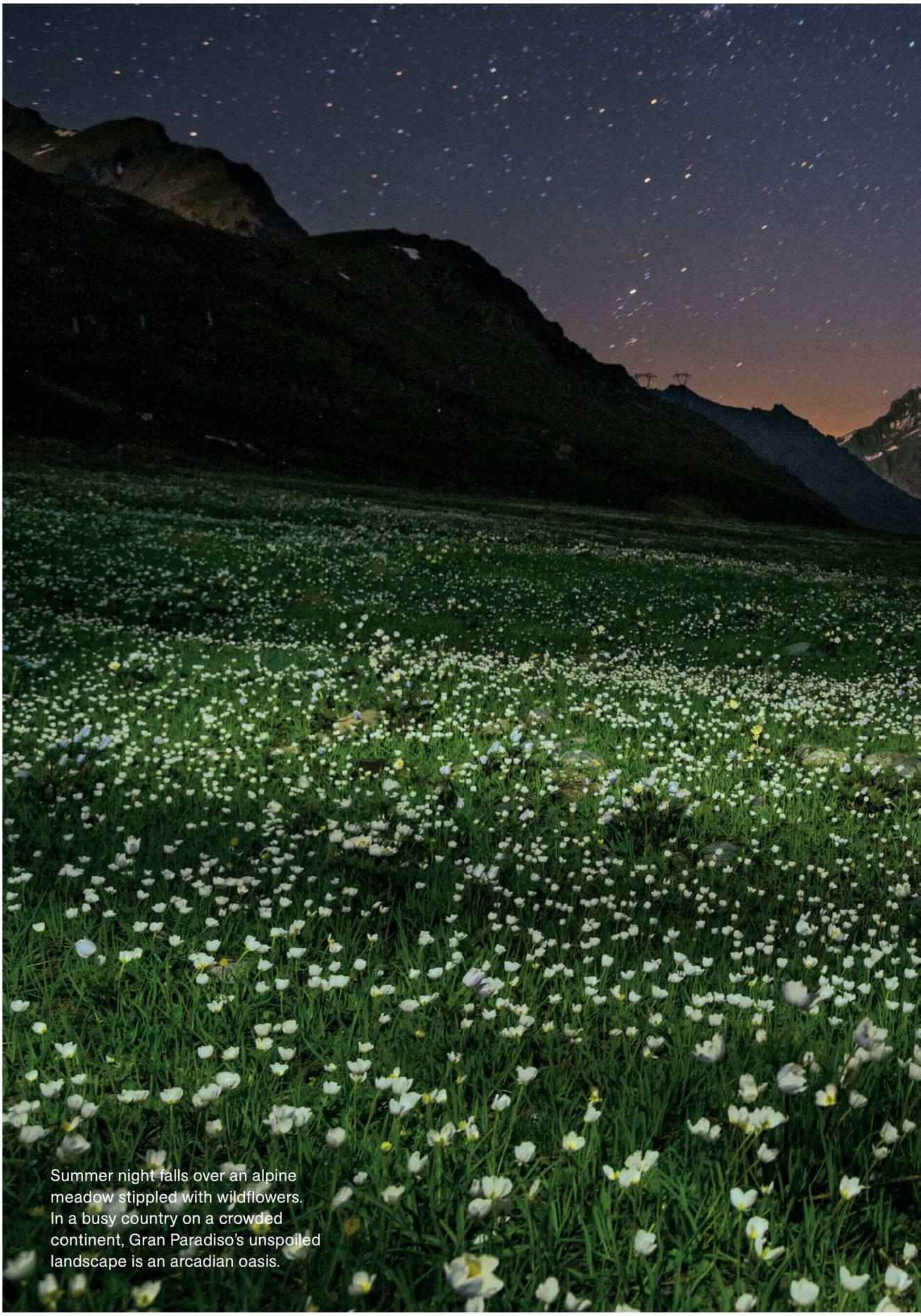
With Gran Paradiso's massif looming beyond a cloud bank, a yellow-billed Alpine chough swoops and soars on thermals and updrafts. The park is home to some hundred species of birds.



Ibex are Gran Paradiso's spirit animal. Their fate and the park's have been entwined for centuries.



A park for all seasons: In spring male ibex establish their hierarchy by locking three-foot-long horns (left). Springtime is also when high-foraging chamois (top) give birth; there are now about 8,000 in Gran Paradiso. In cold weather, a normally reddish brown ermine changes into its white winter coat.



Summer night falls over an alpine meadow stippled with wildflowers. In a busy country on a crowded continent, Gran Paradiso's unspoiled landscape is an arcadian oasis.


TREADIN

Florida's bill is coming due, as the costs of climate change add up around the globe. Adaptations will buy time, but can they save Miami?

GWATER

New luxury towers crowd Sunny Isles Beach, Florida. Miami and its suburbs face a bigger financial risk from flooding in 2050 than any other urban area in the world.


NO TRESPASSING
NO PARKING

Canal merges with cul-de-sac in Fort Lauderdale during a “king tide,” when the Earth, moon, and sun are in an unusual alignment. This October 2014 king tide, which was a foot above the typical high tide, offers a preview of the new normal.

By Laura Parker

Photographs by George Steinmetz

Maps and graphics by Ryan Morris, Alexander Stegmaier, and John Tomanio

Frank Behrens, a gregarious pitchman for a Dutch development company that sees profit, not loss, in climate change, cuts the engine on our 22-foot Hurricane runabout. We drift through brackish water toward the middle of privately owned Maule Lake in North Miami Beach.

It's not quite paradise.

The lake, like so many others in Florida, began as a rock quarry. In the years since, it has served as a venue for boat races, a swimming hole for manatees, and a set for the 1960s TV show *Flipper.* More recently, as if to underscore the impermanence of South Florida's geography, more than one developer has toyed with partially filling in the lake to build condos. Behrens is promoting a floating village with 29 private, artificial islands, each with a sleek, four-bedroom villa, a sandy beach, a pool, palm trees, and a dock long enough to accommodate an 80-foot yacht. The price: $12.5 million apiece.

Dutch Docklands, Behrens's firm, has optioned the lake and is marketing the islands as a rich man's antidote to climate change. As for the risks from rising sea levels, well, that's the beauty of floating homes. The islands would be anchored to the lake bottom with a telescoping tether similar to those that enable floating oil rigs to ride out the roughest hurricanes.

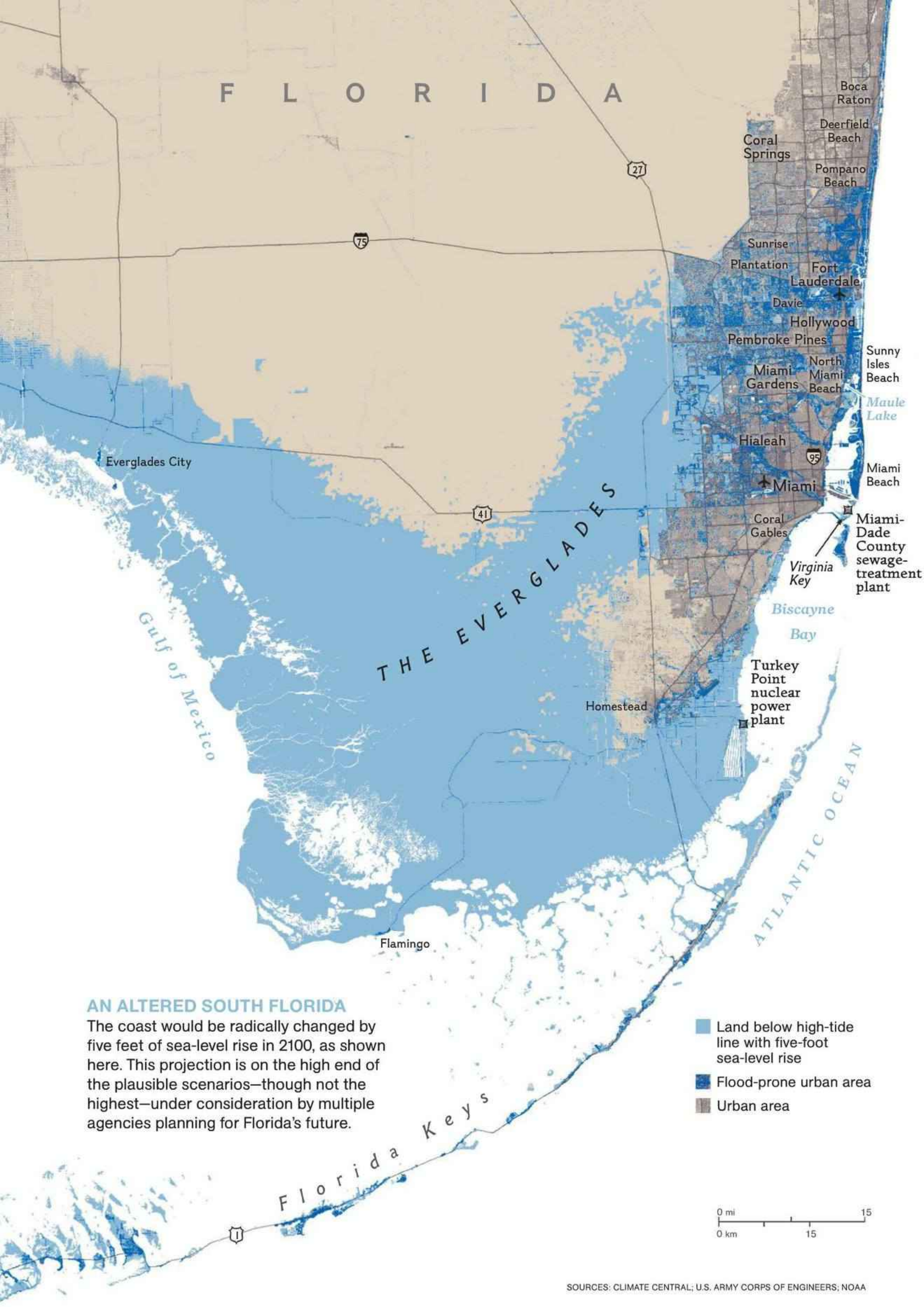
The floating-village plan is part of a frenetic building boom, fueled by wealthy South Americans and Europeans buying with cash, that is transforming Miami's skyline. From our boat we can see construction cranes cluttering the sky along the barrier island of Sunny Isles, where crème de la crème luxury is the hot trend. In a real estate market that celebrates opulence—the $560 million Porsche Design Tower features glass-walled car elevators that stop at every apartment—it was probably inevitable that the greatest threat to South Florida's existence would be used as a promotional strategy.

The Dutch project sounds like one more loopy development in a long history of loopy Florida developments. But its climate-conscious design sets it apart from most of the surrounding high-rises, which are going up with little consideration for the rising seas projected to frequently flood South Florida in the coming decades and to submerge much of it by the end of the century.

These contradictory approaches—plunge ahead, even if only for one more mortgage cycle, or look ahead, preparing for what's coming—reflect a turning point in the discussion about climate change. As warnings about global warming become more dire and the consequences increasingly evident, more and more businesses, and local officials, are factoring climate change into their decisions about the future. They're focused less on reducing the carbon emissions that are warming the planet—that's for political leaders—and more on adapting to severe weather and flooding, which is already occurring as seas rise. And in towns like Miami, where real estate development is an economic engine, businesses are focused on how to keep that growth growing for as long as they can.

AN ALTERED SOUTH FLORIDA

The coast would be radically changed by five feet of sea-level rise in 2100, as shown here. This projection is on the high end of the plausible scenarios—though not the highest—under consideration by multiple agencies planning for Florida's future.



SOURCES: CLIMATE CENTRAL; U.S. ARMY CORPS OF ENGINEERS; NOAA

Home on the Water

Some 2,100 miles of canals built over the past century to drain the Everglades empty into the Atlantic Ocean. Higher seas have already allowed salt water to flow inland through the canals. Gates now keep out most salt water, and massive pumps, including on the Miami River (above), keep canals from overflowing by pushing excess rainwater out to the ocean. Given just two feet of sea-level rise, more than 80 percent of the gates will no longer work. In Biscayne Bay the Venetian Causeway connects Miami Beach to Miami (in the distance, top right) by way of the six man-made Venetian Islands, which epitomize waterfront living. The canals have made developments at the edge of the swampland possible in places like west Palm Beach County (bottom right).

Behrens, who spent his boyhood in Aruba, moved to Miami a decade ago. He signed on with Dutch Docklands in 2013, after it became clear that the region's civic leaders were awakening to the depth of their impending disaster.

The firm's visionaries in Amsterdam foster no illusion that their floating village could save South Florida. It's only one innovative water project among many in the Dutch tool kit that has preserved the low-lying Netherlands since the Middle Ages. Still, Behrens says, the project's value as a high-end venture appeals to investors in a region that will have to be reimagined in the coming decades. And if the floating village succeeds, a range of other possibilities opens up: floating communities with floating parks and floating schools. A floating hospital. "You name it," says the man whose company built a floating prison outside Amsterdam.

"We're in for it. We have really done a job warming our ocean, and it's going to pay us back."

—HAL WANLESS
University of Miami geology professor

"People only see the negative effects of flooding," Behrens says, without a trace of irony. "We need to show people there is a way to make money out of this. For the government, there are tax dollars. For developers, their investment is secured for the next 50 years. There is a lot of money involved in this climate change. It will be a whole new industry."

Florida is a good place to see the costs—and potential profits—of climate change emerging into sharper view. Many coastal places are at risk, but Florida is one of the most vulnerable. While government leaders around the world, in Washington, and even in Florida's statehouse in Tallahassee dither over climate change, here on Florida's southern tip more than a few civic leaders are preparing. Florida's future will be defined by a noisy, contentious public debate over taxes, zoning, public works projects, and property rights—a debate forced by rising waters.

ALONG WITH RISING SEAS, Florida will be battered in the coming decades by extreme weather—dry-season drought and rainy-season deluges—the U.S. government's National Climate Assessment predicts. Heat and drought threaten an agricultural industry that supplies the East Coast with winter vegetables, and they could undermine the three mainstays of Florida farming—tomatoes, sugarcane, and citrus. The rainy season will be stormier, with fiercer hurricanes and higher storm surges.

The most profound disruption will occur along the state's 1,350 miles of coastline. Three-quarters of Florida's 18 million people live in coastal counties, which generate four-fifths of the economy. Coastal development, including buildings, roads, and bridges, was valued in 2010 at two trillion dollars. Already more than half the state's 825 miles of sandy beaches are eroding.

Four southern counties—Monroe, Miami-Dade, Broward, and Palm Beach—are home to about one-third of Florida's population, and about 2.4 million people live less than four feet above the high-tide line. The streets of Fort Lauderdale, Hollywood, and Miami Beach often flood during the occasional "king tides," which are much higher than normal high tides.

The oceans could rise two feet by 2060,

Laura Parker is a staff writer for the magazine. George Steinmetz is a longtime contributor who specializes in aerial photography.

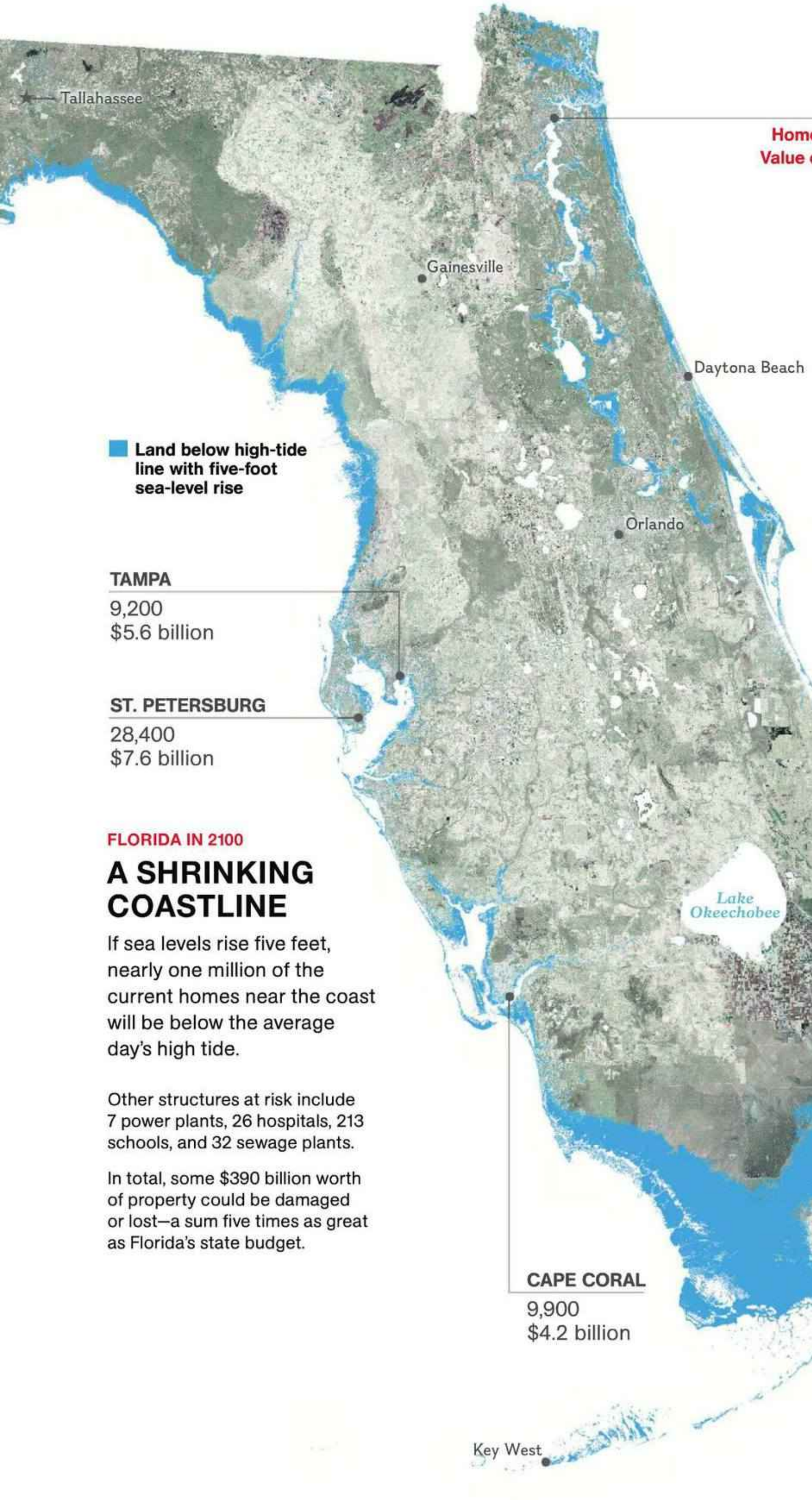
FLORIDA IN 2100

A SHRINKING COASTLINE

If sea levels rise five feet, nearly one million of the current homes near the coast will be below the average day's high tide.

Other structures at risk include 7 power plants, 26 hospitals, 213 schools, and 32 sewage plants.

In total, some $390 billion worth of property could be damaged or lost—a sum five times as great as Florida's state budget.



JACKSONVILLE
Homes affected ▸ 13,200
Value of property* ▸ $5.7 billion

TAMPA
9,200
$5.6 billion

ST. PETERSBURG
28,400
$7.6 billion

FORT LAUDERDALE
45,700
$20.7 billion

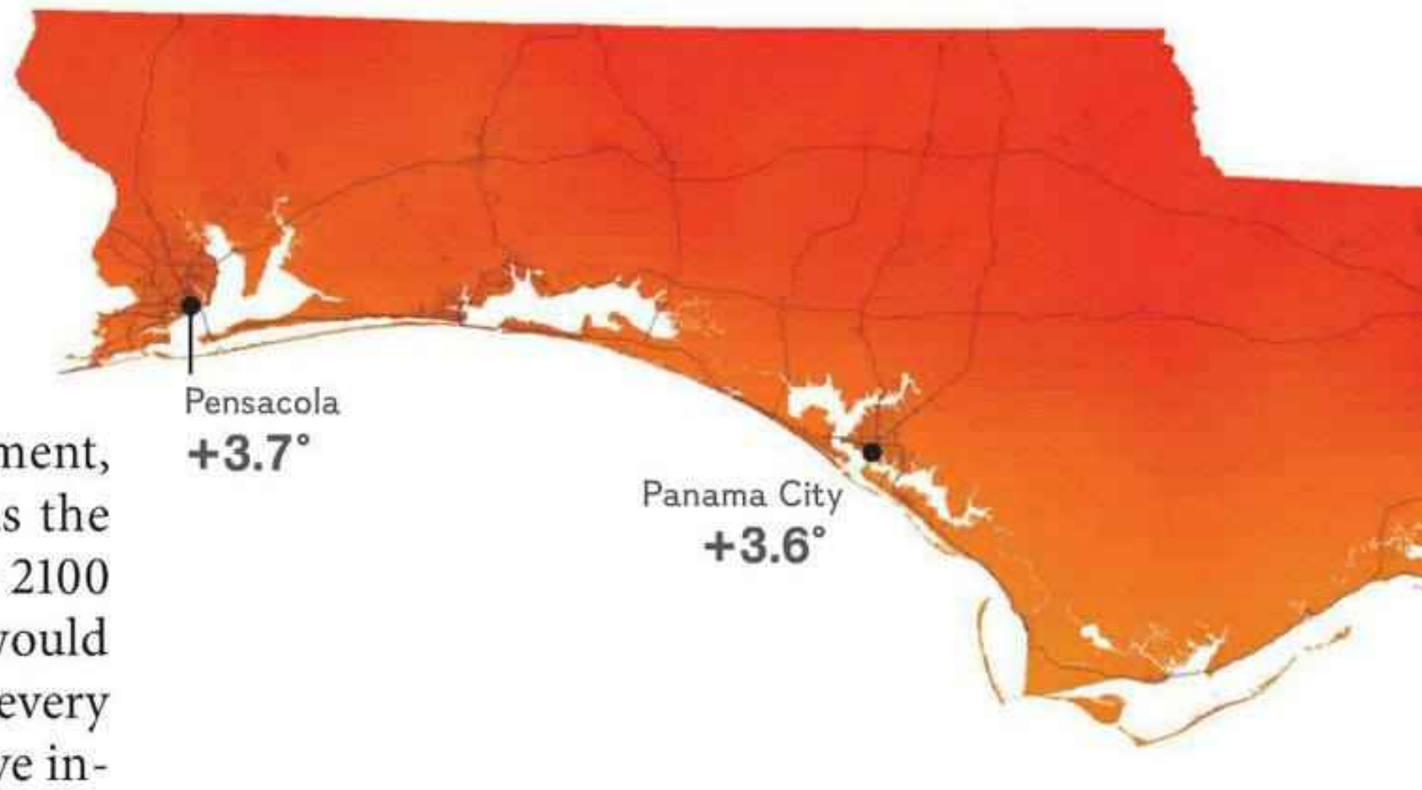
CAPE CORAL
9,900
$4.2 billion

MIAMI**
98,500
$31.4 billion

Hurricanes

Storm surges—the quick rise of sea level caused by heavy winds—will be significantly more damaging by 2100, climate scientists predict. They're often the biggest threat to life and property.

*INCLUDES RESIDENTIAL, COMMERCIAL, AND PUBLIC FACILITIES (IN 2012 DOLLARS)
**INCLUDES MIAMI, PEMBROKE PINES, HOLLYWOOD, AND HIALEAH. SOURCES: CLIMATE CENTRAL; SOUTH FLORIDA WATER MANAGEMENT DISTRICT



according to the National Climate Assessment, as their waters warm and expand and as the Greenland and polar ice sheets melt. By 2100 seas could rise as much as 6.6 feet. That would put much of Miami-Dade underwater. For every foot the seas rise, the shoreline would move inland 500 to 2,000 feet.

A two-foot rise would be enough to strand the Miami-Dade County sewage-treatment plant on Virginia Key and the nuclear power plant at Turkey Point, both on Biscayne Bay.

"At two feet they will be sitting out in the ocean," says Hal Wanless, chairman of the University of Miami's geology department. "Most of the barrier islands will be uninhabitable. The airport is going to have problems at four feet. We will not be able to keep freshwater above ocean levels, so we're going to have saltwater intrusion into our drinking-water supply. Everyone wants a nice happy ending. But that's not reality. We're in for it. We have really done a job warming our ocean, and it's going to pay us back."

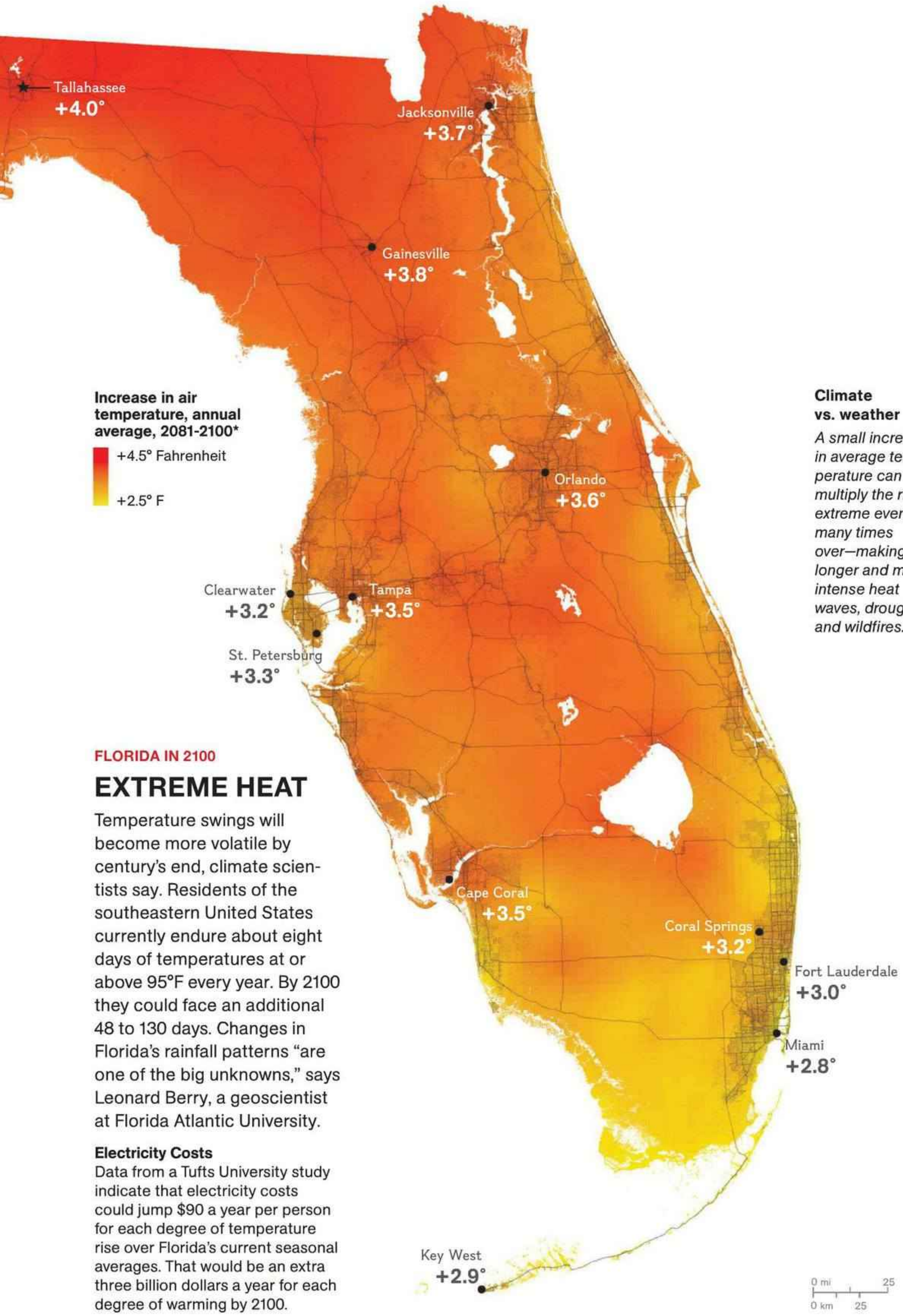
The watchwords are "protect," "accommodate," and "retreat," which sound a lot like a civil engineer's version of the stages of grief.

Wanless, who is 72, didn't think he'd witness the serious effects of climate change in his lifetime. For three decades he was a lonely voice warning that the warming ocean could inundate South Florida. In the 1980s he documented that barnacles were attaching themselves higher on bridge piers in Coral Gables, where he lives, than they were in the 1940s. In recent years he analyzed the shrinking glaciers in Greenland and concluded that the main scientific modeling used to calculate sea-level rise hadn't fully accounted for accelerating ice melt. Last year the United Nations' Intergovernmental Panel on Climate Change gave greater weight to ice-sheet melt in its calculations, raising its projections for sea-level rise.

Florida's long, low coastline may make it more vulnerable, but no region is immune. In 2012, flooding, wildfires, drought, and storms around the country caused more than $110 billion in damages, the second costliest year in U.S. history. In a foreshadowing of severe weather to come globally, Typhoon Haiyan spiraled across Southeast Asia in 2013 and struck the Philippines, killing 6,200 people. That year also saw crop-destroying droughts on nearly every continent, most notably in Africa and South Asia. The Brazilian Highlands, the center of South America's monsoon region, experienced the worst drought since 1979, prompting water rationing. Rapid glacial melting in the Andes and Himalaya will exacerbate water shortages in Peru, India, and Nepal.

The coming decades, the World Bank predicts, will see political instability, food shortages, and famine, leading to the displacement of millions of people. South Asia's and Southeast Asia's heavily populated coasts, particularly those in Bangladesh and Vietnam, could be inundated. Worse, rising seas could invade major river deltas, poisoning them with salt water and destroying some of the world's richest agricultural land. The Mekong River Delta in Vietnam, where 17 million people live and half the country's rice supply is grown, is already battling saltwater intrusion.

IN SOUTH FLORIDA civic leaders have begun to map out their future on their own. Little help has come from the state legislature, which is controlled by Republicans, many of whom



Increase in air temperature, annual average, 2081-2100*

+4.5° Fahrenheit

+2.5° F

Climate vs. weather

A small increase in average temperature can multiply the risk of extreme events many times over—making for longer and more intense heat waves, droughts, and wildfires.

FLORIDA IN 2100

EXTREME HEAT

Temperature swings will become more volatile by century's end, climate scientists say. Residents of the southeastern United States currently endure about eight days of temperatures at or above 95°F every year. By 2100 they could face an additional 48 to 130 days. Changes in Florida's rainfall patterns "are one of the big unknowns," says Leonard Berry, a geoscientist at Florida Atlantic University.

Electricity Costs

Data from a Tufts University study indicate that electricity costs could jump $90 a year per person for each degree of temperature rise over Florida's current seasonal averages. That would be an extra three billion dollars a year for each degree of warming by 2100.

*RELATIVE TO ANNUAL AVERAGE, 1986-2005. SOURCE: NCAR GIS PROGRAM (STATISTICAL DOWNSCALING OF INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE FIFTH ASSESSMENT RCP 6.0 SCENARIO, CCSM4)

remain skeptical of climate science. Rick Scott, the Republican governor, has mostly avoided the subject, repeatedly declaring, "I'm not a scientist." Last summer, after five of Florida's top climate scientists, including Wanless, briefed Scott, he thanked them and said nothing else.

The four southern counties have drafted a general to-do list that would "reengineer" the region, step-by-step, through 2060. A detailed blueprint will be years in the making. But the approach is largely familiar.

"We will do what we always have done," says Joe Fleming, a Miami land-use attorney. "We will dredge and prop everything up."

Harvey Ruvin, a former county commissioner who headed a sea-level-rise task force for Miami-Dade County, lays out the thinking so far: "The

It will take technology not yet imagined to overcome the challenges posed by South Florida's unusual geology.

whole idea is to do this comprehensive capital plan that would include all kinds of things—desalination plants, the lifting of roads, where to raise land, where to create canals. Part of the future has to be raising some land at the expense of other land."

Ruvin knows what he's up against. Procrastination. Disputes over property rights. Long battles over changing zoning and building codes to prohibit building in areas that can't be protected. And he doesn't want to talk about the cost of all that reengineering. "I can't even give you a real number. Maybe $50 billion?" Ruvin muses, though he knows that's low. He's focused on how to pay for long-term projects in a place that operates on capturing short-term gains. "How do you take this to the voters for a bond issue when the county commissioners are afraid to increase property taxes a hair to fund libraries?"

Now the Miami-Dade County Court clerk, Ruvin, at 77, is one of the region's most skillful politicians. He has tried to use the consequences of doing nothing on climate change to prod foot-draggers. It's the same strategy used by Michael Bloomberg, a former mayor of New York City, and Henry Paulson, a former U.S. Treasury secretary; in 2014 they assembled financial heavyweights to catalog the cost of inaction on climate change in every region of the country.

Last year Ruvin invited two executives from Swiss Re, the global reinsurance giant, to brief his task force about Florida's precarious future. The hard-nosed number crunchers created a predictive model that showed the region could expect annual losses from storm-related events to reach $33 billion by 2030, up from $17 billion in 2008. They also said those losses could be reduced by 40 percent if the region acted soon to protect vulnerable real estate. "These kinds of issues cannot just be left for another 10, 20, or 30 years' time," says Mark Way, a sustainability specialist for Swiss Re.

Another factor, Way says, is that subsidized government insurance programs in Florida have skewed the marketplace, leading to underpriced rates that don't reflect the actual risks. "That has the net effect of basically encouraging development directly or indirectly in areas that otherwise don't make any sense."

Already civic leaders are fortifying seawalls and installing pumps. Later come more daunting projects: moving utilities from the coasts and protecting high-value real estate—universities, hospitals, airports, and tourist areas that drive Florida's economy. Their watchwords are

THE ECONOMIC TOLL

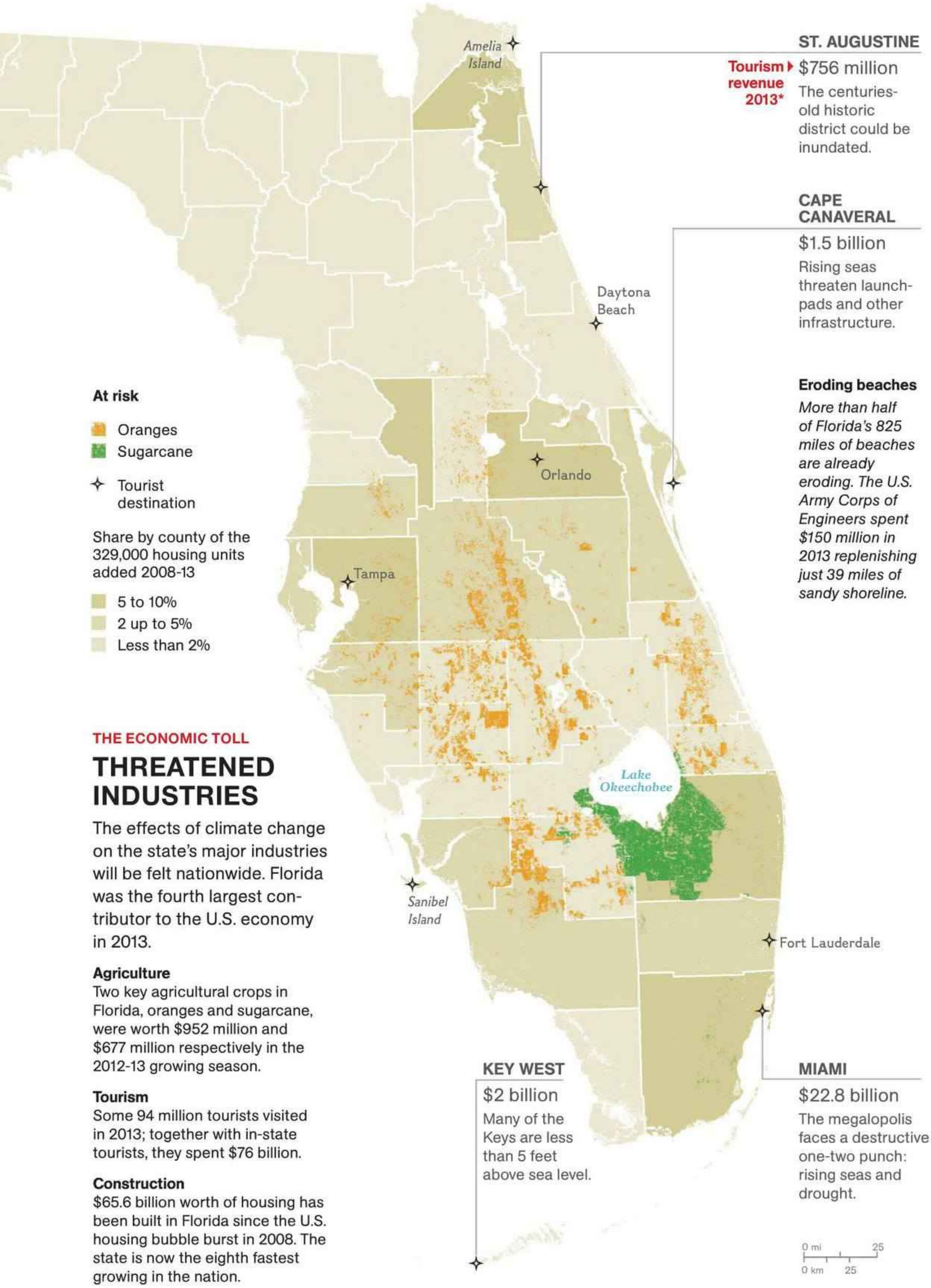
THREATENED INDUSTRIES

The effects of climate change on the state's major industries will be felt nationwide. Florida was the fourth largest contributor to the U.S. economy in 2013.

Agriculture
Two key agricultural crops in Florida, oranges and sugarcane, were worth $952 million and $677 million respectively in the 2012-13 growing season.

Tourism
Some 94 million tourists visited in 2013; together with in-state tourists, they spent $76 billion.

Construction
$65.6 billion worth of housing has been built in Florida since the U.S. housing bubble burst in 2008. The state is now the eighth fastest growing in the nation.



*REVENUE INCLUDES ENTIRE COUNTY. SOURCES: USGS; USDA; U.S. CENSUS BUREAU; COUNTY GOVERNMENTS; JULIE HARRINGTON, FLORIDA STATE UNIVERSITY

Powerful water jets keep pleasure-seekers aloft in Biscayne Bay, near downtown Miami. They're the latest toys in a city that embraces an exuberant aquatic lifestyle, even as rising seas threaten its long-term survival.

"protect," "accommodate," and "retreat," which sound a lot like a civil engineer's version of the stages of grief. But the group is an optimistic one.

"It doesn't do any good to set your hair on fire for something that's 70 years out," says Kristin Jacobs, a former Broward County commissioner and member of President Barack Obama's climate change task force who was elected to the Florida legislature last fall.

She puts her faith in technology. "If you look at settlement across the planet since time began, we evolve to what we need," she says. "Other countries, like Holland, have figured out a way to be resilient. We are looking to be resilient."

THE DUTCH HAVE BEEN TRAWLING for business in coastal cities from Jakarta to San Francisco. They established a beachhead in South Florida several years ago when Behrens founded a Dutch chamber of commerce in Miami.

"These kinds of issues cannot just be left for another 10, 20, or 30 years' time."

—MARK WAY
Swiss Re sustainability expert

In the Netherlands, where two-thirds of the population lives at or below sea level, about 450 companies make water their business, accounting for about 4 percent of the economy. That's on a par with the auto industry in the United States.

Piet Dircke, whose firm, Arcadis, helped New Orleans design new levees after Hurricane Katrina, made his fourth trip from Holland to Miami last summer to participate in a workshop with architects and engineers. Dircke and representatives of four other Dutch firms drew beautiful sketches showing adaptive designs for vulnerable areas.

"Our delta is one of the best places to invest your money," he says. "Rotterdam is a showcase for the world for being an adaptive city. Singapore, Copenhagen, Stockholm—these are all cities that emphasize their water identity and make it a sales objective. Miami could become a water city."

It will take technology not yet imagined to overcome the challenges posed by South Florida's unusual geology: the limestone bedrock that is both a blessing and a curse. Mined, limestone provides fill to build roads and create what constitutes high ground. In its natural state, it's a porous sponge. Water runs through it. It can't be plugged. Seawalls can be raised—as the city of Miami Beach has ordered. But seawalls, no matter how high, can't stop water that bubbles up from beneath.

Even the Dutch would have difficulty protecting the narrow, seven-mile barrier island that is Miami Beach, a top tourist destination.

"Welcome to ground zero of ground zero," says Bruce Mowry, the city engineer, when I meet him at the corner of 20th Street and Purdy Avenue, one of the lowest points in Miami Beach. He's basking in the afterglow of success: $100 million and 20 new pumps kept the city mostly dry during the October king tide. A year earlier a kayaker had paddled along Purdy—not exactly the kind of image that attracts tourists.

The new pumps are part of a $300 million overhaul of the city's antiquated storm drainage system. With 80 new pumps, Mowry hopes to buy Miami Beach another two or three decades. By then, according to the Union of Concerned Scientists, the city could face 237 floods a year.

"Miami Beach will never not exist," he says. "But it will exist in a different way. We may have floating residential areas. We could have elevated roads built up on pilings. We could convert a transportation corridor to water. People ask me, 'Bruce, can this be done?' I say, 'It can be done, but can you afford it?'"

The city has begun an experiment in elevating roads and sidewalks, starting with Purdy Avenue, where a building with a café, liquor

store, and dress shop flooded badly in 2013. The sidewalk and street will be raised by two feet, which should keep water from sloshing into the shops. Two feet won't solve the problem. But with funding and community support uncertain, city officials decided to start small. "Two feet buys the life of this building," Mowry says. "You can't come in and make radical changes."

IF MIAMI HAS A FUTURE as one of the world's water cities, it probably will look more like the Florida Keys than Stockholm. And so I make the trip down the Overseas Highway to Key West, past houses on stilts, marine-equipment shops, and pine trees dying from saltwater poisoning. Golf courses in the Keys are now planted with salt-tolerant grass.

The islands are the exposed remnants of an ancient coral reef. Most are less than five feet above sea level. Reefs can protect coastal regions from storm surges. If healthy, reefs can keep up with sea-level rise, growing higher as the ocean rises. But much of the reef off Florida died in the late 1970s from disease.

"When you dive on the reef today, it's an absolute boneyard of dead coral," says Chris Langdon, a University of Miami oceanographer. Warmer, more acidic oceans are keeping the reef from recovering. Langdon is working to identify a coral that can tolerate those conditions.

"One way to think of their economic value is to imagine if this job went to the Army Corps, and they had to build a seawall 150 miles long, and every few years they had to build it a little higher," he says. "The reefs do that for free."

The highway, also known as U.S. 1, strings together the island chain with 42 bridges. The population in the Keys is limited to the number of people who can be evacuated by vehicle within 24 hours, ahead of approaching hurricanes.

Chris Bergh of the Nature Conservancy joins me at Big Pine Key. He arrived in the Keys from Pennsylvania as a toddler in the back of his parents' 1973 Volkswagen bus and has no plans to move. "I've got a six-year-old," he says. "I expect I'll live out my days here, and he will not. At some point an economist is going to say, 'Look, it's going to cost one billion dollars to redo U.S. 1, and that's only going to buy us 20 more years.' The question is, What will it cost us to buy time so we can keep on keeping on?"

The end of the line is Key West, closer to Havana than to Miami. At City Hall we meet up with Don Craig, a planner who's worked for the city for more than two decades. The city has spent millions in recent years to add pumps, construct a fire station at a higher elevation, and rebuild portions of the seawall that nearly encircles the island. But options are limited.

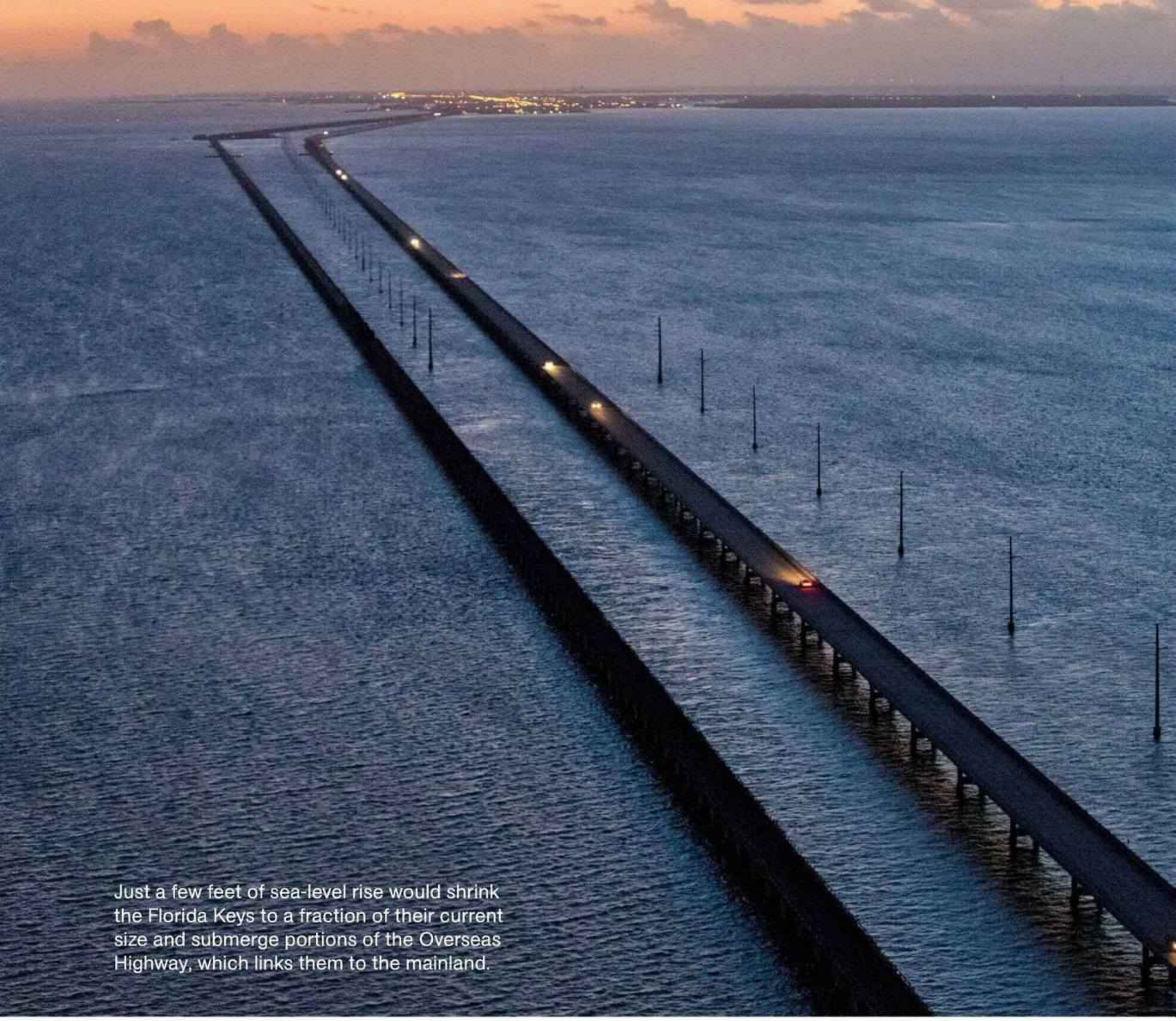
Raising elevations on any large scale is out of reach. "We do not have a nearby source of fill material," he says. "We're 118 miles from the major rock quarries."

When Craig tells people that the Keys' lifeline, the highway, will lie underwater someday, it elicits four responses. "Some become fearful," he says. "Some say, 'Well, I'll be dead, so I don't care.' Others say, 'There is not a consensus that this is going to happen, so why are you telling us this?' The other reaction is mute silence."

Craig's own response: migrate.

He knows something about that. "My parents were Okies," he says. During the Dust Bowl years they lost the family farm in Oklahoma and moved to California, where Craig was born. Some 2.5 million people left the Great Plains in the 1930s to escape the largest man-made environmental catastrophe in American history to date.

THERE'S SOMETHING SURREAL about the pace of construction in a region that may be inundated by 2100. On an early morning flight over northwest Broward County, I watch a dredge scooping up fill to form finger peninsulas on a man-made lake in a housing tract being built against the Everglades. On a boat ride up the Miami River in downtown Miami, I pass a 1.25-acre parcel right on the river's edge that sold for $125 million last spring—a record price here. Nearby, the one-billion-dollar Brickell City Centre, under construction on nine acres, is so enormous it has a cement plant on-site. Across town a $600 million convention center with an 1,800-room hotel is planned.



Just a few feet of sea-level rise would shrink the Florida Keys to a fraction of their current size and submerge portions of the Overseas Highway, which links them to the mainland.

The biggest economic challenge posed by climate change in South Florida may be one that business leaders are loath to discuss—that fear of this slow-speed crisis could stall development.

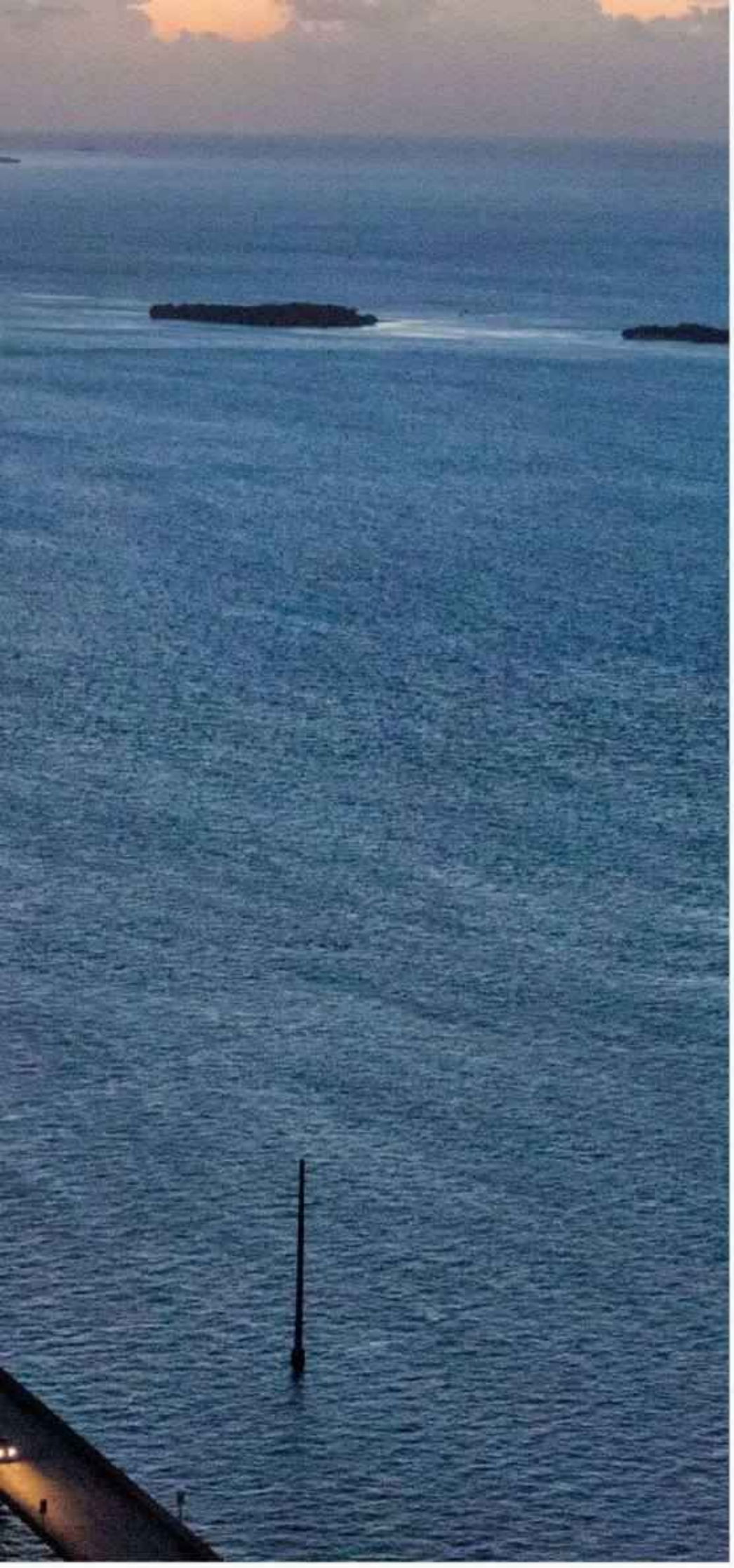
"It's almost like, 'Shhhh. Don't talk about it,' and so it's not real," says Richard Grasso, an environmental law professor at Fort Lauderdale's Nova Southeastern University.

But privately, quietly, conversations are under way. Last fall executives from the region's big banks, insurers, and development companies convened an invitation-only roundtable in Miami with Lloyd's of London. One insurance executive told the group that homeowners in some vulnerable areas already pay premiums that are higher than their mortgage payments.

"There was concern that rising insurance rates are not sustainable and people may be left with no recourse but to leave Miami or go uninsured, which is not an option for those with mortgages," says Kerri Barsh, a Miami land-use attorney who represents Dutch Docklands. "If insurance costs continue to spiral upward, they could have a negative cascading effect on the South Florida economy and beyond."

Unaffordable insurance could trigger an economic calamity that would make the 2008 housing-market collapse here seem like an inconvenience. If homeowners couldn't get insurance, bankers would stop lending, which would create a shortage of cash, which would cause property values to decline and the region's economy to tank.

One way to keep the building boom going is for civic leaders to not look too far into the



future. Thus the four southern counties' focus on 2060 instead of 2100. There's a certain logic to that. The average life span of most buildings is 50 years, and Miami, a mere 119 years old, is continuously rebuilding itself.

"They don't want to look beyond two feet of sea-level rise. This was a deliberate thing not to be too scary," Wanless says. "So there's going to be a lot of throwing money in the ocean before we realize it's time to move on."

Phil Stoddard, in his third term as mayor of South Miami, is one of the few politicians willing to talk about when that time might come. He met me at his house, a one-story stucco bungalow with stone floors (Flood Prep 101), solar panels on the roof, and a large pond that takes up most of the backyard, where he and his wife swim with Lola the koi and an eight-year-old bass named Ackwards.

"I tell people to buy high, sell low," he says drily, pausing to allow the joke to sink in.

Stoddard, also a biology professor at Florida International University in Miami, came up with his own scenario, doodled during a long, dull meeting about climate change that dwelled on sea oats, a native grass whose roots hold dunes in place. "I said to myself, We're looking at something majorly disastrous here—and we're talking about sea oats?" he recalls.

He drew a graph with three lines that show population, property values, and sea level all rising. Then abruptly, population growth and property values plummet.

"Something is going to upset the applecart," he says. "A hurricane, a flood, another foot of sea rise, the loss of freshwater. People are going to stop coming here and bail."

He thinks a real estate sell-off is inevitable. Before that happens, he wants his constituents to be informed. "People ask me this question, 'I'm X years old. I have X amount of net worth in my house. What should I do?' I say, 'If you need the value of that house to retire or to live on, then you want to cash out at some point. It doesn't have to be this year. But don't wait 20 years.'"

Not long ago Stoddard attended a meeting where Wanless presented his analysis showing that the accelerating disintegration of the ice sheets will lead to a more rapid rise of sea levels—faster and higher than the federal government's projections. That night, as Stoddard and his teenage daughter walked on moonlit Miami Beach, he shared what he'd heard.

"She went silent, and then said to me, 'I won't be living here, will I?' And I said, 'No, you won't.' Kids get it. Do you think we should tell their parents?" □

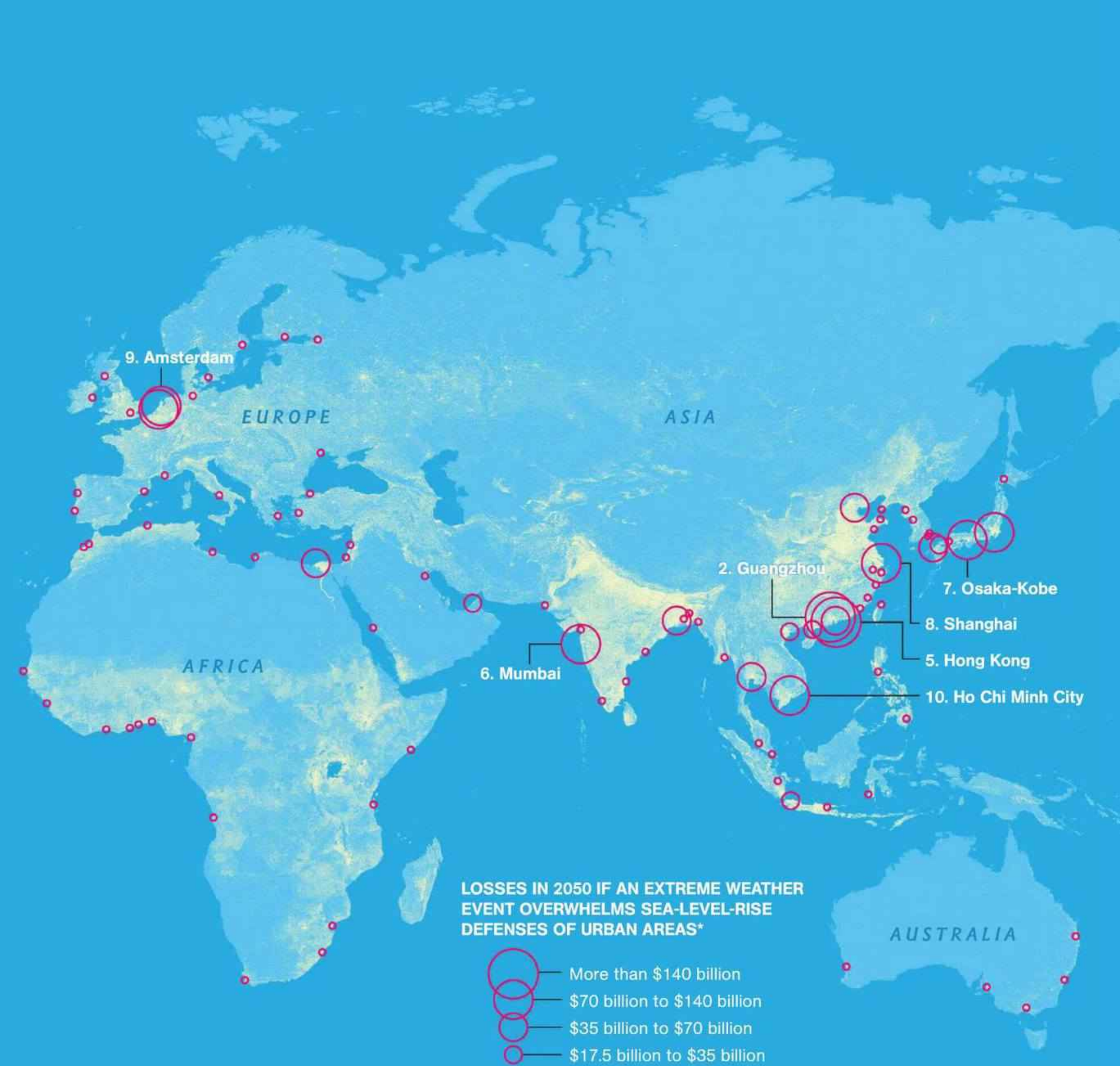
MORE ONLINE

ngm.com/more

NG NEWS

Reef Revival?

Florida's coral reef, which protects the southern coast from storm surges, has been severely stressed since the late 1970s. Can scientists at the University of Miami restore nature's barrier?



LOSSES IN 2050 IF AN EXTREME WEATHER EVENT OVERWHELMS SEA-LEVEL-RISE DEFENSES OF URBAN AREAS*

- More than $140 billion
- $70 billion to $140 billion
- $35 billion to $70 billion
- $17.5 billion to $35 billion
- Less than $17.5 billion

POPULATION DENSITY, 2013

High — Low

TOP 10 COASTAL URBAN AREAS

Miami	$278 billion
Guangzhou	268
New York-Newark	209
New Orleans	191
Hong Kong	140
Mumbai (Bombay)	132
Osaka-Kobe	108
Shanghai	100
Amsterdam	96
Ho Chi Minh City	95

*ASSUMES CITIES CONTINUE TO BUILD PROTECTIONS ON PACE WITH SEA-LEVEL RISE TO MAINTAIN A CONSTANT RELATIVE RISK OF FLOODING (IN 2005 U.S. DOLLARS)
SOURCE: STÉPHANE HALLEGATTE, ET AL., *NATURE CLIMATE CHANGE*, SEPTEMBER 2013

The Cost of Climate Change in 2050

Higher seas mean greater financial exposure for coastal cities, where populations are growing and the value of buildings and infrastructure is increasing. More frequent flooding would likely disrupt insurance underwriting and with it the financing that drives development in cities such as Miami. If sea levels rose just 16 inches by 2050, the flood damage in port cities could cost a trillion dollars a year. With ingenuity and significant investment, new fortifications might limit flooding, but cities would need to keep improving and maintaining them. Inevitably an extreme weather event would overwhelm defenses. World Bank researcher Stéphane Hallegatte, who has estimated how much such events could cost urban areas at mid-century, says, “Protection protects us until it fails.”

Drowning World

Story and Photographs by
GIDEON MENDEL

Extreme weather, sometimes related to climate change, seems to be everywhere these days. And yet it can be hard to see the impact on individual lives. I began documenting that impact in 2007, when I photographed two floods that occurred within weeks of each other, one in the U.K. and the other in India. I was deeply struck by the contrasting effects of these floods and the shared vulnerability that seemed to unite their victims.

Since then I have visited flood zones around the world, traveling to Haiti, Pakistan, Australia, Thailand, Nigeria, Germany, the Philippines, and the U.K. again. In flooded landscapes, life is suddenly turned upside down, and normality is suspended.

Portraits rest at the heart of this project. I often follow my subjects as they return home through deep waters, and work with them to create an intimate image in their flooded homes. Though their poses may be conventional, their environment is disconcertingly altered. Often they're angry about their circumstances or the inadequate response from the authorities. Many want their plight to be witnessed and want the world to know what has happened to them.

I shoot on film with old Rolleiflex cameras. Digital would be easier, but the texture of film has a particular quality for me, and the process of using an old camera adds formality and gravitas to the situation.

The flood is an ancient metaphor in many cultures, a destructive force that renders humans powerless. As weather becomes more extreme, the biblical is becoming literal. □

In 2011 Thailand's worst floods in 50 years swamped the village near Bangkok where Wilaiporn Hongjantuek lives—but she still went to the store to shop for her family.

Storms that swept the British Isles during the winter of 2013-14 brought record rainfall and widespread flooding to parts of England. In a plains region locally known as Somerset Levels, thousands of acres of agricultural land were underwater for a few months, including Roger Forgan's farm.

In the Somerset village of Burrowbridge, builder Dave Donaldson and his daughter, Heather, 12, pose in their flooded home. Though the rest of his family evacuated for a time, Dave stayed to try to save the livestock from the watery devastation that he says "looked like something out of a weird disaster movie."

Joseph and Endurance Edem, with son Godfreedom and daughter Josephine, stand before their gated home in Igbogene, Nigeria. In 2012 Nigeria endured its worst flooding in a half century. “I was scared,” says Josephine, “and thought we were going to die in the water.” At least 360 people did.

Between July 2011 and January 2012, 65 of Thailand's 77 provinces were declared flood disaster zones. The monsoon-driven floods that deluged his home near Bangkok had "something to do with climate change," says Sakorn Ponsiri. "It could happen again... We will have to be more prepared."

Floodwaters surround a house and school building near Muzaffarpur in the Indian state of Bihar. People described the 2007 floods there as the worst in living memory. The flooding closed schools, affected millions of people, and claimed more than a thousand lives.

The 2014 floods in England “felt surreal,” says Jeff Waters, here with his wife, Tracy, in their garden in Staines-upon-Thames. The water stopped rising just short of their doorsill. To the west, in the village of Moorland, Shirley Armitage wasn’t as lucky: Chest-deep water filled the house (above) that her father built in 1955.

In the Loupe

With Bill Bonner, National Geographic Archivist

All Eyes on the Revolution

An optometrist's shop sign looks up from the loupe in this 1914 street scene in Zacatecas, Mexico. Rebel leader Pancho Villa's forces had just taken the crucial railway town from President Victoriano Huerta's federal troops. The Battle of Zacatecas was one of the Mexican Revolution's bloodiest. Some 7,000 died; thousands more were wounded.

This photograph was likely acquired for, though not published in, stories on Mexico that ran in the July 1916 issue of *National Geographic*. The man shown carrying a coffin (at center) is perhaps the only clue to the message inscribed on the back of the print: that this picture was once among "the latest war photos." —*Margaret G. Zackowitz*

PHOTO: PAUL THOMPSON, MUTUAL FILM COMPANY/NATIONAL GEOGRAPHIC CREATIVE

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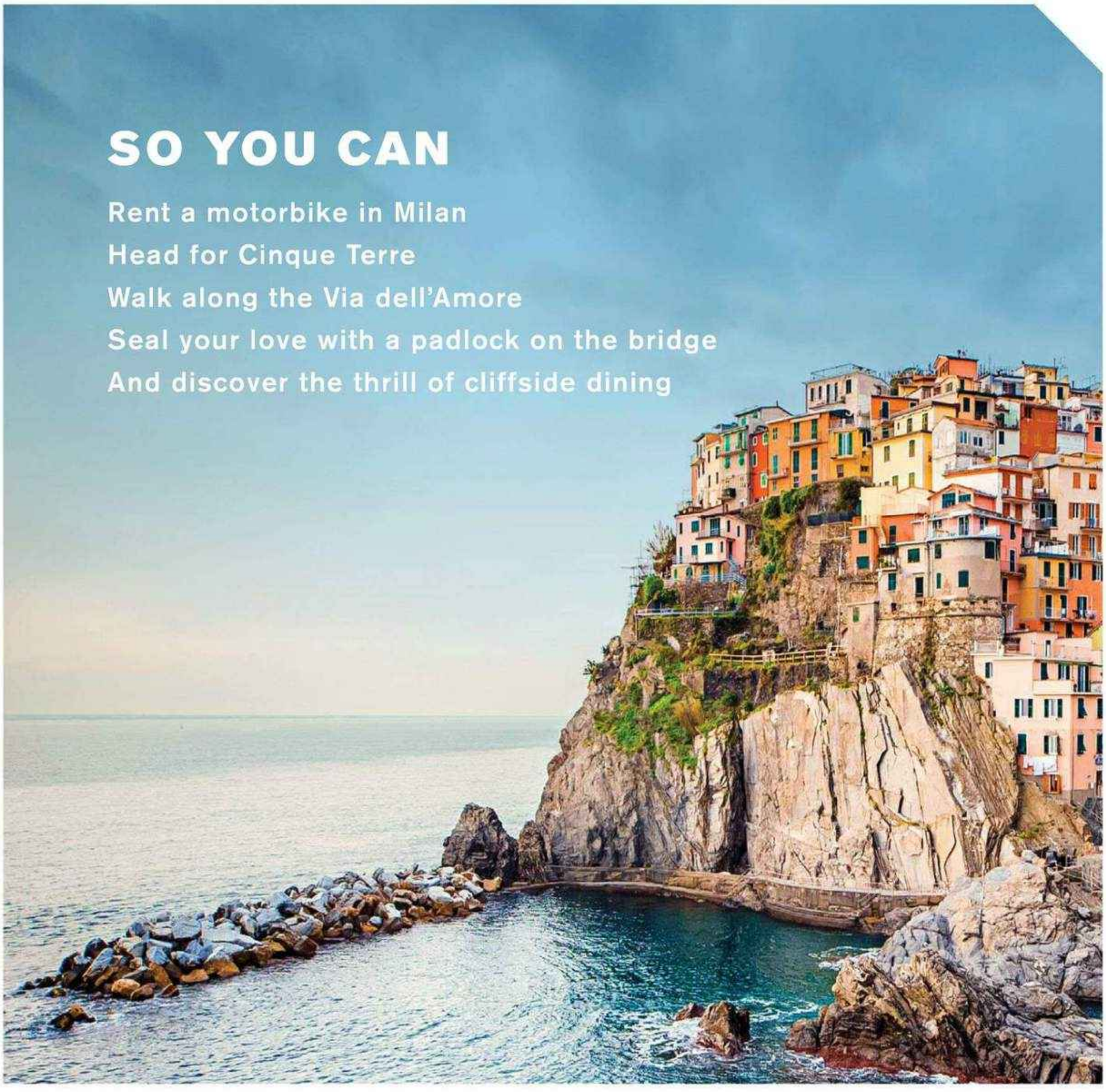

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