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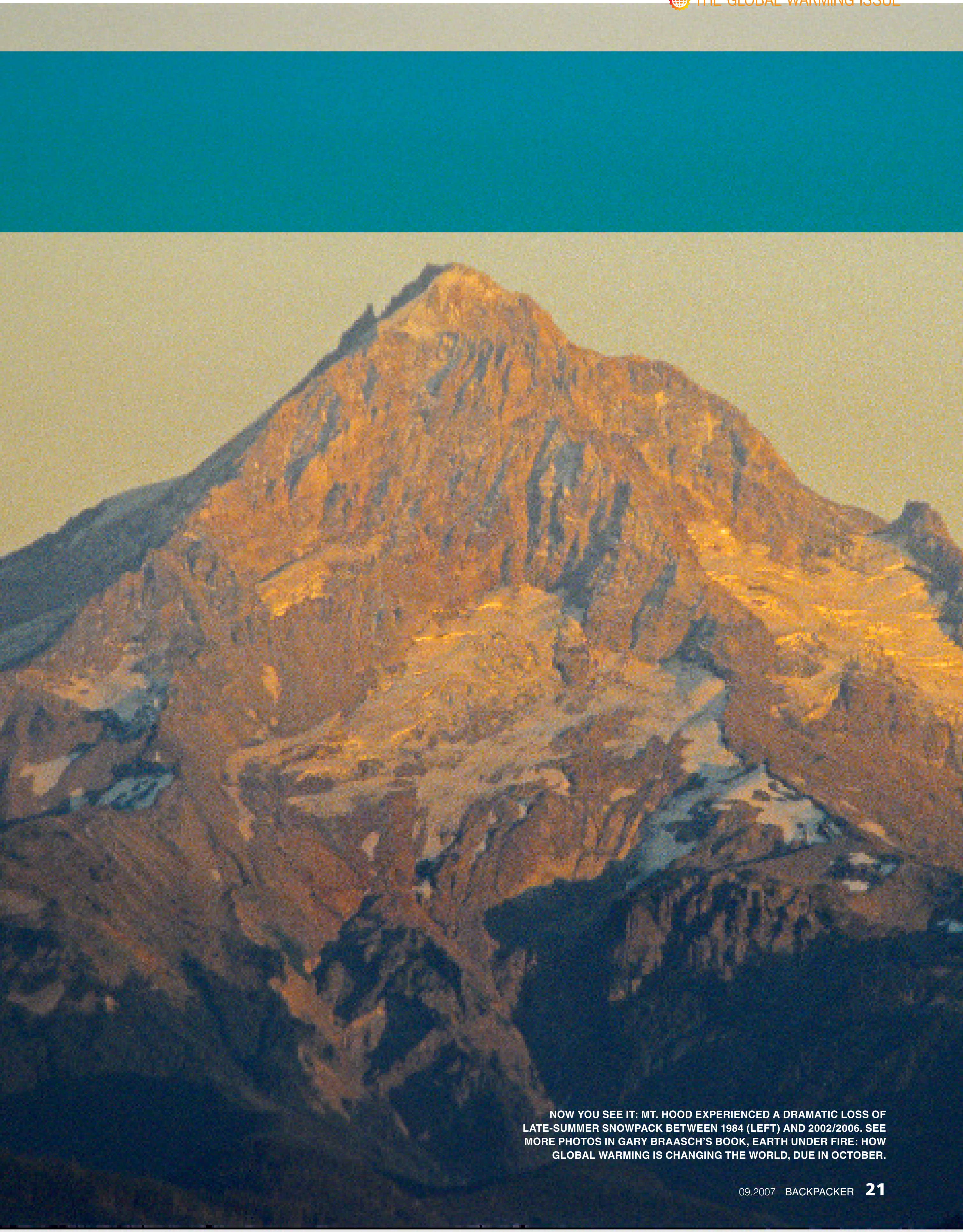
PHOTOS BY GARY BRAASCH



NOW YOU SEE IT: MT. HOOD EXPERIENCED A DRAMATIC LOSS OF LATE-SUMMER SNOWPACK BETWEEN 1984 (LEFT) AND 2002/2006. SEE MORE PHOTOS IN GARY BRAASCH'S BOOK, EARTH UNDER FIRE: HOW GLOBAL WARMING IS CHANGING THE WORLD, DUE IN OCTOBER.

The Future of Mountains

If you love mountains—and the glaciers, snowfields, and alpine meadows that cling to their slopes—better grab your pack now. Climate change is melting ice and snow as we speak, making these high, cool places the most visible warnings of a warming world. Why should you care? In addition to altering the scenery and jeopardizing vulnerable species in iconic parks, rising temperatures threaten access to the peaks and ridges you love to hike. Plus, what happens in mountains directly affects lowland habitats and ecosystems many miles away. Here's an overview of the key changes scientists are tracking.

Reporting by Michael Lanza

1 | 2 | 3 | 4 | 5 Threat level

1. More frequent debris flows 4

Ranges in the Northwest will see more and stronger winter storms, like the 2006 deluge that dumped 18 inches of rain on Mt. Rainier.

When glaciers retreat, they deposit moraines of loose rocks and soil in steep valleys. Heavy rain erodes these unstable slopes, mixing runoff and debris into powerful floods that can wipe out trails, roads, and bridges, says Paul Kennard, a river geomorphologist at Mt. Rainier National Park. Destructive debris flows can occur in any season, but peak in late fall and early winter, when there's little snow to absorb and slow runoff. A 2005 study predicts a 140 percent leap in "extreme precipitation events" in that November-to-January window in the Pacific Northwest over the next 100 years.

2. Thirstier hikers 4

Retreating mountain glaciers will reduce meltwater flows to downstream drainages.

The glacial runoff that quenches your thirst and sustains Western trout populations will diminish as ice sheets in the Pacific Northwest continue to recede. Annual summer flow in North Cascades National Park's Thunder Creek, the most heavily glaciated drainage in the Lower 48, has decreased by 30 percent in 150 years. Nearby Mt. Baker's Deming Glacier has retreated 1,000 feet since 1987, endangering the 20 percent of summer stream flow it supplies for the city of Bellingham. As glacial runoff slackens, river crossings will become easier, but some important water sources for hikers and animals miles downstream will dry up.

3. Higher alpine zones 4

Plant and animal species endemic to Appalachian and Rocky Mountain peaks will be squeezed out by encroaching vegetation.

Species adapted to alpine zones can't easily migrate up or down slope, which makes them vulnerable to climate change. That could create trouble for Southern Appalachia's bald peaks and New England's alpine ridges, as rising temperatures push treeline higher. Most endangered are rare wildflowers like diapensia and alpine azalea in New Hampshire's White Mountains, and northern flying squirrels and salamanders in the Great Smokies. In the West, bighorn sheep, raptors, pikas, mountain goats, marmots, and many wildflowers won't escape the advancing foliage and rising temperatures.

4. Stronger avalanches 4

Warming temperatures will increase the frequency and strength of snow slides across the country.

Two winter climate trends—more precipitation falling as rain, and more freeze-thaw cycles—will increase the number and intensity of avalanches, making it harder for hikers and skiers to predict them. Scientists also fear that new slide patterns will alter the existing treeless chutes that avalanches scour into mountain slopes. Plants like cow parsnip and glacier lily flourish in these niche habitats, providing dependable forage for grizzlies and bighorn sheep.

5. Smoggier mountain skies 4

Rising temperatures could worsen air quality in New Hampshire's White Mountains.

Nitrous oxides and hydrocarbons from car exhaust combine on warm, sunny days to produce ground-level ozone, an oxidant that irritates the mucus membranes in humans and animals, and that damages plants. In addition to blanketing major cities, this smog accumulates in alpine regions like the White Mountains. As a result, ozone readings atop Mt. Washington are generally 2 to 5 times higher than at lower elevations. Because higher temperatures increase ozone production, global warming will continue to degrade the air quality and the views on the Northeast's high peaks.

6. Smaller glaciers

By mid-century, much of the permanent ice in America's national parks will have vanished.

Nearly all of the world's mountain glaciers have receded as average global temperatures have risen 1°F in the last century, according to the IPCC's Climate Change 2007 report. In our backyard, 60 percent of Sierra Nevada glaciers and 40 percent of the perennial ice in North Cascades National Park has melted since the 1880s. Because carbon lingers in the atmosphere for decades after it's produced, warming will continue even if emissions are cut. In the Pacific Northwest, the most glaciated region in the Lower 48, temperatures are predicted to rise another 1°F in the next 20 years, melting all but the high-elevation ice sheets, like those capping Mt. Rainier.

7. Soupier tundra

Melting permafrost could make Alaska hiking a nightmare and triple current atmospheric CO_2 levels.

Eighty percent of Alaska's interior, including most of Denali National Park, rests on permafrost, a layer of frozen soil. Scientists predict that rising temperatures will thaw the top 10 feet of half of the Northern Hemisphere's permafrost acreage by 2050, aggravating existing damage to roads and buildings and turning solid tundra in prime hiking destinations into impassable bogs. Simulations run by the National Center for Atmospheric Research predict that 90 percent of the world's permafrost could turn to slush by 2100. The real danger, however, is the resulting release of underground methane, a greenhouse gas that is 21 times more potent at trapping heat than CO_2.

8. Less snowpack

Sierra snow levels are thinning, and they're melting away three weeks earlier than they did 50 years ago.

Peak runoff for Yosemite's waterfalls is shifting from early summer (when most hikers visit) to spring, when many trails remain inaccessible. The earlier melt will also cause some streams to dry up in July, a month early. Even if we reduce CO_2 emissions, forecasters believe California temps will rise 3 to 5.5°F over the next few decades, causing the Sierra snowpack to decline by 30 percent. If we don't, snowpack could shrink by 90 percent, ending most winter recreation and turning snow-fed streams into dry washes.

Hot Times

1750
Alaska's Glacier Bay is buried under an ice sheet 4,000 feet thick and up to 20 miles wide.

1850
Glacier National Park has more than 150 glaciers.

1975
Rising temperatures in the Sierra Nevada cause peak runoff earlier in the year.

1988
The Intergovernmental Panel on Climate Change (IPCC) is established.

1990s
The Paradise Ice Caves vanish from Mt. Rainier National Park as the Paradise Glacier retreats.

1994
Mt. Rainier's glaciated area is 20 percent smaller than it was in 1913.

1999
Aerial photos show that North Cascades National Park has lost 13 percent of its glacier area since 1971.

2003
Glacier National Park has 73 percent less ice coverage than it did in 1850.

2007
The IPCC predicts a global temperature increase of 2 to 11.5°F by 2100.

2030
The last glaciers vacate Glacier National Park as mean summer temps hit 63°F. Meanwhile, Sierra snowpack is down 30 percent, threatening California's winter tourism industry and water supply.

2040
Colorado Rockies snowpack declines 24 percent.

2050
Half of the Arctic's permafrost acreage has melted to a depth of 10 feet. Spring runoff in Western rivers is down 10 to 20 percent.

2090
Average temperatures in the Sierra Nevada have risen 4.5°F, advancing snowmelt runoff by another month.

Predictions are based on current emissions trends.

ILLUSTRATION BY KEVIN HAND

ICE MACHINE: THE COLUMBIA GLACIER DUMPS 2 CUBIC MILES OF ICE (75 MILLION SEMI-TRUCKS' WORTH) INTO THE SEA A YEAR.

Columbia Glacier
Prince William Sound, AK

In 1982, the 37-mile-long Columbia Glacier began to retreat. As it did so, it revealed how rising temperatures and sea level are accelerating the loss of coastal glaciers.

Flowing Ice
>> Flowing as fast as 80 feet per day (a record pace for a glacier) the Columbia is receding because it calves icebergs faster than it generates new ice.
>> Having already lost 10 miles of ice, the Columbia will recede another 10 miles in the next two decades before reaching land.

Pulling Apart
>> Much of the Columbia's recession is caused by the depth and pressure of the seawater that surrounds it.
>> The buoyancy of ice causes the submerged glacier to move faster, stretching the headwall like taffy.

Rising Water
>> Higher sea levels (generated in part by glacial melt) increase the strain on tidewater glaciers, causing more calving.

The Greening of Glaciers
Plucky plants take over from ice.

When Alaskan glaciers recede, they often leave behind rocky moraines, and it doesn't take long for pioneering plants to transform these dead zones into new gardens. But there's a catch: The dark-colored vegetation absorbs more sunlight than ice does, pushing temps higher, and the new growth can grow into an impassable forest.

[0–5 years] Mosses appear first on bare rock. As soil accumulates, hardy wildflowers like fireweed and horsetail arrive via windborne seeds.
[6–49 years] Arctic flowers like white dryas and purple saxifrage grow as a thick ground-covering heath. Dryas add more nitrogen to the soil.
[50–100 years] Sitka alder spreads and grows into the dense tangles that bedevil bushwhacking hikers.
[101–300 years] Spruce and hemlock groves dominate the alder and establish a mature and thriving forest.

The End of Ice

Alaska's most famous and active glaciers are poised for extinction.

Muir Glacier in southeast Alaska's Glacier Bay National Park used to be Bruce Molnia's favorite place to kayak. In the early 1980s, he regularly paddled among the blue and white icebergs, watching harbor seals congregate on the bus-sized blocks, safely separated from bears and wolves. Shorebirds like marbled murrelets filled the sky, and pods of orcas hunted the cold waters. When Molnia, a glacier expert with the U.S. Geological Survey, returns to the Muir Glacier today, he sees a headwall that has retreated a quarter-mile from the water, large lumps of brown ice rotting in the dirt, and a bay devoid of both icebergs and seals.

Alas, Muir's retreat is hardly unique; almost all of Glacier Bay's rivers of ice are melting, as are virtually all the lower-elevation glaciers in Alaska. The major cause is that state's rapid warming. In the past 60 years, its average temperature has increased 3°F, more than twice the rate recorded worldwide. Winter and spring temperatures rose the fastest in that period, according to the Alaska Climate Research Center, moving up 7°F and 3.5°F, respectively, at Juneau, 50 miles from Glacier Bay.

This warming trend is directly related to the melting of lower-elevation glaciers, says Molnia, who has studied them for nearly 40 years. He recently surveyed the 2,000 largest glaciers in Alaska and concluded that 99 percent of them are thinning, stagnating, or in retreat. The only ones that aren't melting are high-elevation glaciers, those above 8,000 feet.

Change is hardly new for this area. In 1750, the bay didn't exist: It lay beneath a river of ice 4,000 feet thick and as wide as 20 miles. By the time John Muir visited in 1879, the tongue of ice that had touched the waters of Icy Strait had retreated 30 miles, revealing to him a bay where at night "the surge from discharging icebergs churned the water into silver fire." Although the region's glaciers have been slowly melting for 500 years, recent studies indicate that the icemelt is accelerating, likely due to rising carbon emissions.

Today, this 65-mile-long fjord, flanked by peaks and dotted with countless islands and channels, attracts several thousand kayakers and dozens of cruise ships each summer. But for how much longer? At the current rates of recession, Molnia says, 10 of Glacier Bay's 11 tidewater glaciers will become landlocked within 50 years. The loss of these glaciers will reduce the park's recreational appeal—and change the ecology of the bay. When a glacier retreats onto land, as Muir did, its ice thins out and becomes embedded with mud and rocks. The shorebirds and seals once attracted by the fish- and nutrient-rich glacial currents seek other feeding zones. Within a few generations, Molnia predicts, none of the ice for which this park was named will reach the water. Anyone fancy a five-day paddling trip through Muddy Flats National Park?

PHOTOS BY (FROM LEFT) RICH REID/ANIMALS ANIMALS; STEPHEN H. SCHNEIDER

BEAT THE HEAT: TERRY ROOT ESCAPES THE MIDDAY SWELTER WHILE BIRD-WATCHING LAST JULY IN AUSTRALIA.

Digging for Clues

A big-picture biologist unearths threats to songbirds, salamanders, and a peak-loving furball.

When Terry Root scored the highest marks in her math class as a 14-year-old in Albuquerque, her father announced that girls weren't supposed to be good at numbers. So Root decided to become a mathematician. And she got pretty far—until she fell in love with birds.

So Root transferred her statistics skills to her Ph.D. work in biology at Princeton, where her computer analysis of bird counts from across the United States proved that temperature, not competition, exerts a greater influence on avian ranges, upending the conventional wisdom that had been advanced by her colleagues and thesis advisors.

As climate-change science gathered steam in the late 1990s, Root's skill at meta-analysis—seeing the big picture—became critical to quantifying the impact of rising temperatures. In 2003, she published an article in *Nature* that analyzed 143 scientific studies and concluded that global warming was already affecting animal and plant populations, and could accelerate extinctions.

Root's current research takes these findings a step further. She believes continued warming will tear ecosystems apart, instead of shifting them intact to new climates, as Darwin once speculated.

For evidence, she points to the mountaintop-dwelling pika, a fist-sized relative of the rabbit that can't tolerate hot conditions. In Nevada and Utah, pikas have moved to higher elevations to escape rising temperatures. Some colonies have disappeared, while the survivors are running out of space. "Because pikas can't move above talus fields," Root explains, "they are toast." Other alpine species, from songbirds to salamanders, also face climatic upheaval. Some animals will migrate to survive, she says, but others will disappear as ecosystems collide.

Now based at Stanford University, Root, 53, mixes teaching and research with expeditions to the North Pole and Papua New Guinea, as well as occasional birding escapes to New Mexico. With all she's seen, she says she can no longer ignore the moral imperative of climate change. This realization came several years ago in Australia when she learned that the tiny Mallee emu-wren she had just spotted faced certain extinction. "I've turned a corner," she says. "When you see that one species is about to cause the extinction of greater than 40 percent of existing species on the planet, it's hard to sit back. Can we save everything? No. But I want to save as much as I can."

Florence Williams

LOW FLOW: SPRING RUNOFF IN THE NORTH CASCADES WILL END MUCH EARLIER WITHOUT DEPENDABLE MELTWATER.

Cascades Meltdown

The Lower 48's most glaciated region is losing its ice at an astonishing rate.

Looming above the Pacific Northwest's plunging waterfalls and ancient forests is something even rarer: a vast collection of glaciers. Seventy percent of the Lower 48's glaciers are in the North Cascades and Olympics. Mt. Rainier, with year-round snow and ice, supports the largest concentration of glaciers on a single peak outside of Alaska. But recent studies indicate that lower-elevation ice, and the potential for July snowball fights, will soon diminish on these mountains.

For most of the last century, the glaciers in the Pacific Northwest have been in full-scale retreat. Between 1913 and 1994, Rainier lost a quarter of its glacial volume, and satellite mapping in 2002 showed some of its biggest glaciers—the Nisqually, Winthrop, South Tahoma, and Carbon—at or near their historic minimums. Seven of Mt. Hood's 11 glaciers have shrunk an average of 34 percent since 1900, while in North Cascades National Park, ice sheets have decreased in size by 13 percent since 1971.

The region's glaciers will continue to melt as the climate heats up. Scientists with the University of Washington's Climate Impacts Group predict that the Northwest will warm about 1°F in the next 20 years—nearly as much as it did in the past century. Most vulnerable are the small glaciers (250 acres and smaller) that make up almost half of the region's ice sheets. Only those at the highest elevations will outlast the century.

This widespread retreat also impacts the appearance and accessibility of mountains. Andrew Fountain, a climate researcher at Portland State University, predicts that the snowy slopes of Mt. Hood will become drier and less vegetated, much like California's Mt. Lassen, within 50 years. Likewise, retreating glaciers and disappearing snow have already exposed more rock on Rainier's summer climbing routes, says Mike Gauthier, the peak's lead climbing ranger. Less snow means tougher footing, more rockfall hazards—and less climbing appeal. "For me, the whole area will become a lot less interesting," says Fountain. "You're losing one of the most attractive features of hiking in the Northwest, its snow and ice."

Mt. Rainier National Park, WA

Rising temps help spawn superstorms that can obliterate trails, bridges, and roads.

On November 6 and 7, 2006, nearly 18 inches of rain fell on Mt. Rainier, generating the worst flooding in the park's 108-year history. That storm could be a sign of the future. A 2005 Purdue study predicts a 140 percent leap in November-through-January "extreme precipitation events" for the Pacific Northwest in the 21st century. These deluges could also generate the debris flows that proved so destructive at Rainier. Paul Kennard, a river specialist at the park, says these floods have increased in frequency. "We've been getting about four a year for the past four or five years," he says.

How a debris flow forms

›› When glaciers retreat, they leave behind what Kennard calls "over-steepened terrain"—crumbling moraines susceptible to washouts.

›› Heavy rainstorms then trigger debris flows—destructive slurries of mud, trees, and boulders with the consistency of liquid concrete. November's storm set off at least 6 flows on Mt. Rainier.

›› The flows gouge out enormous gullies that grow deeper with each successive flood.

Double Trouble The same November 2006 storm that walloped Mt. Rainier caused $7 million in damage to Glacier National Park's Going-to-the-Sun-Road. In June 2007, workers installed a 100-ton steel girder bridge where landslides had washed out a 108-foot section of pavement.

PHOTOS BY (FROM LEFT) DAVID MUENCH; RICHARD DURNAN

Winter Wipeout

Early thaws and more rain will frustrate wilderness enthusiasts who like to play and travel in the snow.

If you strap on snowshoes or skis when the white stuff gets too deep for boots, it's time to wonder if the fun is going to last. Many climate experts are projecting warmer, wetter winters that will disrupt snow recreation from the Whites to the Sierra.

Northeast Snowshoes and skis from New York to Vermont are already collecting more dust than powder. New England winters are warmer (with average temps up 4.4°F between 1970 and 2000) and muddier (with 15 to 25 fewer days of snow cover since 1970). If temperatures rise 3.6°F—the most conservative estimate— in this century, the ski season will shrink by two more weeks, and more midseason thaws will mean more snowmaking and temporary resort closures. If New England temperatures leap by 7.2°F, the worst-case scenario, all but a few geographically favored resorts could close shop.

Pacific Northwest The Cascades snowpack has declined 30 percent since 1945, according to a February 2007 report by the University of Washington. To explain it, scientists point to the 1.5°F jump in average regional temperatures since 1900. More winter rain and lack of snow at lower elevations has turned snowshoeing and cross-country skiing trails into muddy paths, and also hurt the region's ski economy, which experienced its worst-ever season during the winter of 2004–05. More soggy winters are expected. Climate models predict average Northwest temperatures will rise an average of 0.5°F per decade over the next century. As a result, the length of a typical ski season at Summit at Snoqualmie, a resort with a 3,000-foot base in western Washington, could decline by 28 percent by 2025. The season at the slightly higher Stevens Pass resort (4,050 feet) could shrink by 14 percent, but also experience a 50 percent increase in winter rain.

Rocky Mountains The high elevations of Colorado's major ski resorts have protected the state's $2 billion industry from global warming, at least so far. The average winter temp at Aspen (with a base of 8,000 feet) is expected to rise 1°F in the next two decades, as much as it climbed in the previous 50 years. But only the resort's lower slopes might lose snow cover. At the same time, changes in weather patterns over the Gulf of Mexico could boost winter precipitation from 20 to 70 percent, and make winter storms more intense. As a result, Colorado resorts are worried, but not panicked: When lack of snow cancelled World Cup ski races in Europe last fall, well-blanketed Colorado resorts offered to host them.

Sierra Nevada Spring temperatures have increased 2° to 3°F since 1950, accelerating snowmelt by 3 weeks and requiring resorts to make snow throughout the season. Climate models predict average temperatures in the Sierra will rise 5° or 6°F over the next century. As a result, the region's snowpack is predicted to shrink between 30 to 90 percent, reducing the length of the ski season in California and Nevada by as much as 6 weeks.

In the Soup
For those 3-season backpackers who believe global warming will extend the hiking season, that logic is all wet. Scientists predict that warmer winters will produce more days of cold rain and sock-soaking slush.

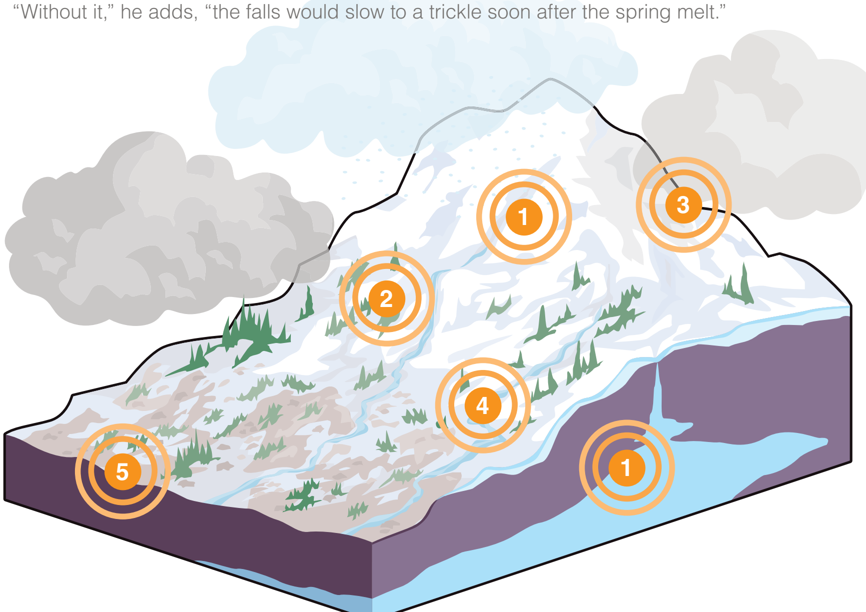
snowmelt

Declining snowpack from Utah to Pennsylvania will make it harder to find reliable water in the backcountry, enjoy decent ski runs, and paddle classic rivers. *By Jason Stevenson*

For hikers, a snow-draped peak is a summit goal, a perfect photograph, or a tantalizing daydream. What we sometimes forget is snow's critical role in sustaining life on earth. Water released from melting ice and snow supports plants, wildlife, and millions of human beings from L.A. to Boston. But as global warming continues to melt glaciers, spawn more winter rain, and dissolve snow earlier in the spring, the runoff that flows over Yosemite Falls—and out of your faucet—may slow to a trickle. Here are the factors threatening snowpack and the water it generates.

[1] Melting up high

Rising alpine temperatures are causing mountain snow to melt faster, which means less groundwater to supply late-season runoff for many Western drainages. Although some precipitation flows directly into streams and lakes, a significant portion leaches into the ground to recharge subterranean aquifers and rivers. This groundwater can seep through rock layers for years before it returns to the surface, providing a slow-release reservoir that keeps mountain streams flowing in summer and fall. "More than half the water flowing over Yosemite Falls has been underground for more than 10 years," says Mike Dettinger, a USGS hydrologist. "Without it," he adds, "the falls would slow to a trickle soon after the spring melt."



[5] Diminishing water

Backpackers who prefer to explore up high will see the results of declining snowpack before anyone else. Mountain slopes get less runoff than plains and valleys, making alpine zones early-warning stations for drought. But because snowpack is predicted to decline 24 percent in the Rockies over the next 35 years and as much as 40 percent across the West by 2060, we'll all face a water crisis. At particular risk are Western states, which draw 75 percent of their water from mountain snowmelt. Backpackers can adapt by carrying more water or choosing alternate routes, but cities of millions will require large-scale solutions.

Jason Stevenson

[2] Freezing ground

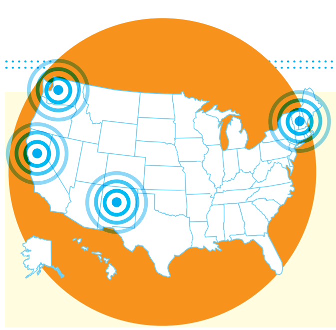
Frozen soil can block meltwater from infiltrating the ground, keeping more runoff on the surface and increasing the probability of erosion and floods. During a typical winter, heavy snow insulates the ground and prevents it from freezing. But when drifts are patchy or shallow, or temperatures fluctuate rapidly, a layer of surface frost can develop and block water penetration. Global warming could increase occurrences of surface frost by thinning snowpack at lower elevations and producing spring thaws and rainstorms that wash away the snow before the soil warms up.

[3] Darkening snow

Fresh snow reflects 90 percent of the solar radiation that hits it. But snow darkened by pollution and dust melts earlier and faster, according to Thomas Painter, a hydrologist with the National Snow and Ice Data Center. His fieldwork in Colorado's San Juan Mountains showed that dust-covered snow melted 25 days earlier than clean snow in 2005, and 30 days earlier in 2006, following a surge in dust storms. Most of the dust blew in from the adjacent Colorado Plateau, but some storms originated in China. Painter is concerned that large dust storms could become more frequent as global warming makes landscapes more arid, creating a positive-feedback loop that darkens and melts Rocky Mountain snow a bit earlier each spring.

[4] Accelerating runoff

In Western streams, peak runoff—the date when snowmelt is at its highest level—has sprung forward by almost 3 weeks in the last 50 years, according to the USGS. It's happening because average temperatures in winter and spring are rising faster than in other seasons. This warmer, moister air results in more winter rainstorms that turn snow to slush. The Pacific Northwest has seen the biggest shift in peak runoff, but drainages in the Sierra, Rockies, and southeast Alaska are experiencing similar cycles. Across the West, these changes are causing larger spring floods, plus reduced stream flow during the drier summer months.



When the Snow Goes

Four adventure havens that won't be the same.

North Fork of the American River, CA
Earlier snowmelt shrinks the famous whitewater season as peak flow occurs earlier each year.

Bandelier National Monument, NM
Trickling Jemez Mountains snowmelt dries up the already rare backcountry water sources.

Stevens Pass, WA
Dramatic loss of low-elevation snow closes snowshoe and cross-country ski trails at this Cascades resort for good.

Tuckerman Ravine, NH
More frequent winter rains and escalating temps stop April and May tele-skiers in their tracks.

ILLUSTRATION BY BRYON THOMPSON

VISION THING: RISING TREELINE WILL NIX VIEWS LIKE THIS ONE FROM MAINE'S CARIBOU MOUNTAIN. INSET: ALPINE AZALEAS ARE ALSO AT RISK.

Running Out of Space

Rising treeline threatens the Northeast's best views.

New England peakbaggers take note: That head-in-the-clouds feeling of hiking above timberline to gaze over a sea of summits could soon be a memory. The region's average climate is already 1.7°F warmer than it was a century ago, and is expected to heat up at least another 5°F by 2100, according to a 2006 report by the Union of Concerned Scientists. That mean's the region's archipelago of bare peaks could be overtaken by advancing brush and trees within several decades.

Most at risk will be the panoramic summit views that attract one million hikers to the White Mountains every year. The fall foliage season will lose its luster as colors evolve over more weeks and brilliant maples are replaced by duller brown oaks. In subalpine zones, hardwoods and grasslands will flourish to overtake conifer forests of red spruce and balsam fir. In fact, the 2006 edition of the Appalachian Mountain Club's *Field Guide to the New England Alpine Summits* has a new appendix explaining how global warming is causing local plants and animals to adapt to the region's new climate.

A Cure for Baldness

Climate change will overtake a rare Southern ecosystem.

Appalachian summits in the South, which are remnants of a past Ice Age, will see dramatic changes with a warming climate. Slopes above 4,400 feet in Virginia, Tennessee, and North Carolina—alpine islands surrounded by warmer zones downslope—support red spruce and Fraser firs that don't appear again until the Adirondacks and Whites, almost 1,000 miles to the north. These cool-climate trees provide habitat for rare animal species, including the northern saw-whet owl, northern flying squirrel, and pygmy salamander. But if temperatures rise as predicted (3.6°F by 2099), warmer climate zones will allow hardwoods and grassland to supplant the spruce-fir forests, and animals that can't migrate will die out. Also, some open balds will fill in with mountain laurel and rhododendron, becoming the impassable "laurel hells" known to hikers. Other balds will remain open due to grazing, intentional clearing, or poor soil conditions, but the views from those peaks will lose their unique appeal.

Blooming Too Soon

New England's alpine palette grows duller.

Milder winters and sudden spring thaws are sowing confusion on mountain slopes. They are causing wildflowers to bloom too early, exposing them to late-season frosts and disrupting their timing with pollinators. For the past three years, citizen scientists affiliated with the Appalachian Mountain Club's Mountain Watch program have recorded species like diaspensia and alpine bilberry flowering in mid- to late-May, two to three weeks ahead of schedule. Within the next several decades, expect remnant Arctic species like diapensia and star-shaped pink alpine azaleas (above) to disappear from New England peaks. And when the tiny Robbins' cinquefoil vanishes from Mt. Washington, it will be be gone from the planet for good.

PHOTOS BY JERRY & MARCY MONKMAN

PHOTOS BY (CLOCKWISE FROM TOP LEFT) KEN ARCHER; ERWIN & PEGGY BAUER/ANIMALS ANIMALS; PATTI MURRAY/ANIMALS ANIMALS; CHUCK GRAHAM

Species We Can Kiss Goodbye

Conditions in America's mountains will push these animals into extinction—or Canada.

What's killing pikas in the Rocky Mountains? It's the heat. Scientists predict that these adorable "rock rabbits" will die off within the next few decades as rising temperatures overwhelm their ability to adapt or migrate. In general, alpine animals are faring poorly in a warming world, mainly due to their elevated, isolated habitats. Species that depend on fir forests, frigid winters, and heavy snowpack are hitting a topographical wall that blocks their attempts to escape the heat. As a result, scientists expect climate change to spawn a new wave of endangered and locally extinct plants and animals, starting with the species described below.

[1] American pika

The high-pitched chirp of this tiny mammal could soon fade to silence within alpine zones in the Rockies and Sierra. Intolerant of heat and dependent on talus slopes for food and protection, the pika is running out of high-elevation terrain to escape rising temperatures. As a result, it could be one of global warming's first documented extinctions. In the last 40 years, nearly a third of the pika population in the Great Basin (the drainage between the Rockies and Sierra) has vanished. Donald Grayson, a University of Washington evolutionary ecologist who authored another key study, describes this animal's future as "markedly insecure."

[2] Wolverine

This tenacious scavenger, known to challenge a grizzly bear over a carcass, has staved off two centuries of persistent trapping and habitat destruction. But the effects of global warming might finally chase it out of its northern Rockies santuary. Slow to reproduce and requiring an enormous range, wolverines depend on deep snowpack for both shelter (a den for giving birth in early spring) and food (animals killed by cold and avalanches). But its preferred habitat will shrink as winters get milder and snowline rises; climate models predict a snowline increase of 150 feet per decade, which will force the wolverine steadily northward.

[3] Marmot

According to a long-term study at the Rocky Mountain Biological Laboratory, the internal clock of the yellow-bellied marmot is wildly askew. The animal is coming out of hibernation 38 days earlier in the spring than its forebears did 23 years ago, and the study's author, biologist David Inouye, blames climate change. The consequences of this premature wakeup? The marmot awakens to more snow cover (22 inches deeper on average), and the lack of food can force it back to bed. When it rises the second time, it burns muscle instead of fat to jump-start its metabolism—which makes it vulnerable to starvation and predation.

[4] Bicknell's thrush

Every spring, this sparrow-sized brown songbird migrates from the Caribbean to the northern Appalachians, where the entire population breeds in conifer forests above 4,000 feet. Notoriously shy and picky, the Bicknell's thrush nests almost exclusively in balsam firs. As global warming threatens its tree of choice, this rare bird has become of the most range-restricted breeding species in eastern North America. A 2002 study predicted that a temperature increase of 1.5 to 6.3°F by 2100 could thin balsam trees in New England by 96 percent as advancing hardwoods such as beeches and yellow birches crowd them out.