ECOLOGY

Mount St. Helens, Revisited

The devastating eruption 20 years ago has transformed scientific thinking about the nature of volcanoes and how ecosystems recover from them

At 8:32 a.m. on 18 May 1980, a little-known peak in the Washington Cascades erupted, unleashing a blast that felled trees over an area of about 600 square kilometers. The blast was followed, in quick succession, by the largest avalanche in recorded history (comprising 2.3 cubic kilometers of rock), mudflows, scorching heat, and billowing ash that turned day to dusk at least 100 kilometers downwind. But the eruption did more than rearrange the landscape near now-famous Mount St. Helens; its intellectual aftershocks have continued to reorder scientific wisdom in both volcanology and successional ecology.

At a meeting* commemorating the 20th anniversary of the explosion, volcanologist Kathy Cashman of the University of Oregon, Eugene, said that prior to the event, geologists thought huge debris avalanches such as the one that roared off Mount St. Helens were fairly rare. But Mount St. Helens has taught geological sleuths how to recognize the traces of such avalanches, enabling them to identify more than 400 prehistoric slides—some on a scale that would dwarf the one from Mount St. Helens. Another lesson was that seemingly minor eruptions, like those that followed the events of 18 May, can have devastating consequences—unleashing surprisingly severe mudflows—if hot ash or lava falls onto snow (*Science*, 19 May, p. 1181).

Using satellite imagery, geologists were also able to track Mount St. Helens' ash plume with unprecedented accuracy. Although such plumes are the least deadly of volcanic perils, they are a threat to airplanes, whose engines can be overheated by the abrasive ash.

Far more dangerous than ash plumes are lava dome eruptions, which occur when sporadic eruptions extrude pasty lava, like toothpaste from a tube. At Mount St. Helens, a dome began forming in late 1980; by the time volcanic activity ceased in 1986, it had reached a height of about 280 meters.

Lava domes pose a threat if they collapse and tumble down the mountain during the course of an eruption—a common occurrence when they form on steep slopes, as happened a few years ago on Montserrat in the West Indies, said Cashman. Volcanologists therefore seized the opportunity for closeup study of the sequence of 17 eruptions that created the dome on Mount St. Helens. Armed with seismological records and data gathered from clambering around the dome to measure swelling, cracking, and escaping gases, volcanologists became confident enough to predict similar events elsewhere. "This was incredibly important," Cashman said, "because no one knew we could make predictions for this type of volcano. The most notable success was Mount Pinatubo in the Philippines, where hundreds of thousands of people were evacuated. It shows that we can live more safely with volcanoes."

Remarkable recovery. Conifers and wildflowers have come back in profusion near the edges of the blast zone.

Leftovers and chance

In ecology as well as geology, the eruption of Mount St. Helens has rocked scientific thinking; indeed, many preblast theories were flattened along with the forest.

Immediately after the blast, the land looked barren, lifeless. Millions of dead trees lay like windrows of hay, pointing in the direction of that all-consuming wind. Mostly they faced directly away from the mountain, but in some areas they fell in swirling patterns where the blast had been deflected around ridges or hillsides. Where slopes shielded them from the worst of the blast, their skeletal forms still stood in an eerie forest of ghostly, bleached trunks. According to ecological convention, the land should have been virtually sterile: Ecosystems would need to rebuild themselves from scratch in the slow process of succession.

The truth turned out to be far more complex. Scientists now know that the mountain's remarkable recovery was driven by two previously overlooked forces: random chance and leftovers from the preblast landscape—which forest ecologist Jerry Franklin of the University of Washington, Seattle, calls "legacies" of the prior ecosystem (*Science*, 19 May, p. 1183).

These legacies include both the "ghost forest" and the uprooted trees of the blowdown region. The decaying wood, it turns out, provided a banquet for wood-boring insects, which in turn attracted woodpeckers and flickers. Elsewhere, the roots of toppling trees dragged soil, seeds, and forest-floor plants high above the blanket of smothering ash, where many flourished.

It was chance that dictated the nature of these legacies. Not only were individual plants and animals spared by simply being in the right place at the right time, but the date and time of the eruption were also vital to the course of the mountain's recovery. Regeneration would have been much slower—and different—if the eruption had occurred in midsummer, noted Charlie Crisafulli, a research ecologist with the U.S. Forest Service's Pacific Northwest Research Station in Olympia, Washington. In May, many lakes were shielded by 30-centimeter caps of ice, beneath which the blast had little impact. Similarly, lingering snow patches protected underlying vegetation, creating scattered ecological oases called refugia. Just as important, the blast occurred during the day, when nocturnal animals were safely in their burrows, giving those that weren't too deeply buried an opportunity to dig back to the surface.

Even in an area called the "pumice plain," where the old ecosystem was so deeply buried that there was little legacy to jump-start its recovery, chance played a much greater role than anticipated. Prior theory, noted Jonathan Titus, an ecologist at Biosphere 2 in Oracle, Arizona, said that each species of pioneering plant needs a distinct combination of such factors as moisture, slope gradient, soil stability, and elevation above sea level. But when his research

* Mount St. Helens: 20 Years of Biological Research and Lessons Learned, 13 May at Mount St. Helens National Volcanic Monument.

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team painstakingly measured these and other parameters at hundreds of sites in an attempt to determine the factors governing the locations at which each species had begun growing, they found little correlation. The seeds, Titus said, arrived on the wind and lodged in particular locations purely by chance. If they found enough moisture, they sprouted. "Another species could be there just as well," he said.

Amphibians and gophers

Farther from the mountain, some of the most unexpected survivors were amphibians. In fact, at a time of worldwide decline in amphibians (*Science*, 30 April 1999, p. 728), those near Mount St. Helens are thriving.

One species is the western toad, listed elsewhere as endangered. Part of the reason for the animal's population boom at Mount St. Helens, Crisafulli said, is that its predators—ravens, jays, and snakes—haven't yet recovered. But in addition, the tadpoles feed on algae in lakes, and the demise of tall, lakeshore trees has provided more sun for algal growth.

The tailed frog, whose tadpoles live in creeks rather than lakes, presents a similar success story. Before the blast, said Charles Hawkins, a stream ecologist at Utah State University in Logan, the species was presumed to need the damp shade of creeks in old-growth forests. But on the edges of the blast zone, where scattered islands of trees survived, biologists were stunned to find 15 times more tadpoles than in undisturbed old growth. "This completely flew in the face of conventional wisdom," Hawkins said.

It turns out that only the adults need shade. Like young toads, frog tadpoles feed on algae, which is normally in short supply beneath an old-growth forest canopy. So the ideal frog habitat is a mixture of forest shade and sunny creeks—exactly the conditions created at Mount St. Helens. "One of the lessons we've learned is that homogeneous landscapes aren't all that good for animals," Hawkins said. "Sometimes you need patchy landscapes—especially if a species has a complex life cycle, like the tailed frog."

At least as dramatic is the recovery of 12 of the region's 15 species of salamanders. In some of the lakes, Crisafulli said, salamander counts are among the highest he's ever seen. This is surprising enough in lakes that had salamanders prior to the blast. But the eruption created more than 120 new lakes and ponds, and somehow the water-loving creatures crossed kilometers of seeming desert to colonize them.

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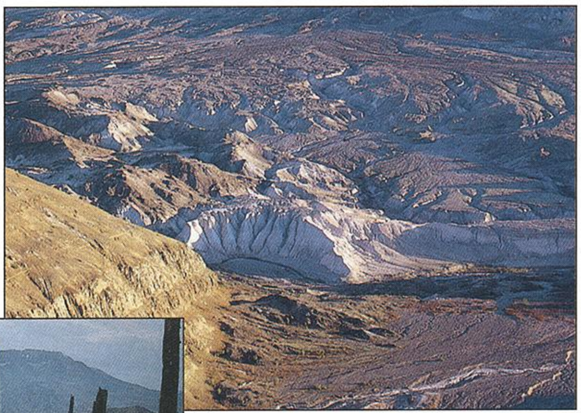
The salamander survival story begins with the sheltering ice that covered their ponds at the time of the blast. But the tale Crisafulli told centers on their multistage life cycles. Classically, salamanders hatch and grow in ponds and then metamorphose into land-roaming adults, which return to the water to breed and lay eggs. Some reach full sexual maturity without growing lungs. These neotenic salamanders spend their entire lives in the ponds—ensuring that even in the sun-scorched blast zone, there will always be a next generation. Some members of that next generation will themselves be neotenic; others will metamorphose into terrestrial forms and will strike out overland in search of new homes. At Mount St. Helens today, most of these migrants die. But a few get lucky. Perhaps they encounter a fortunate series of rainstorms; perhaps they find seep springs at critical locations.

The salamanders were also aided by pocket gophers, hailed by Crisafulli as "the unsung heroes" of the mountain's recovery. The gophers live underground in meadows and clearcuts, where they eat roots and tubers. When the eruption converted the entire blast zone into one big meadow, it created "gopher heaven," particularly as plants began to regrow. The gophers' excavations, in turn, brought seeds to the surface and mixed the rich underlying soils into the nutrient-poor ash and pumice. The gophers also created kilometer after kilometer of underground tunnels. The salamanders, Crisafulli discovered, found these gopher subways and used them to disperse far more broadly than they could have aboveground. It was an important lesson in the value of unexpected ecological linkages.



Blast zone. At the epicenter *(above)*, recovery is slow. Mats of dead trees still float on Spirit Lake *(left)*, while others stand sentinel on the ridge above.

Surprising boosts

Ecologists were also stunned by the ability of small mammals to find refugia, or habitat islands, among barren pumice. Standard ecological wisdom said these animals could only reach these oases via migration corridors, and that they wouldn't cross broad, open spaces. But mice, voles, chipmunks, and ground squirrels seemed undeterred by multikilometer journeys; even shrews weighing as little as 7 grams somehow made the treks. Crisafulli now believes animals can reach isolated habitats so easily that when they are absent, biologists shouldn't blithely assume the reason is that they can't get there. Rather, he said, it probably means the habitat isn't ready for them.

These and similar observations prompted him to speculate that ecological succession isn't driven by "average" events throughout a region. "It's the unusual events that make the difference," he said. "The fact that most of the voles are in the blowdown zone isn't as interesting as the few that make it to the pumice plain."

Although recovery has been unexpectedly rapid, the landscape near Mount St. Helens has been irrevocably changed by the eruption. Even in areas where the only impact was a few centimeters of ashfall, the forest floor is visibly altered. Gone, for instance, are the lush mosses that once carpeted it, replaced by an unusually large number of baby trees. "It's going to be a long time before we have forests like we did before," said Joe Antos, a terrestrial plant ecologist at the University of Victoria in British Columbia. The form these new forests will ultimately take is unknowable. Perhaps the overriding lesson from the eruption is that so-called "climax forests" are dynamic, not static. They are periodically affected by outside events, be they volcanic eruptions, forest fires, or massive windstorms. Each of these, Antos said, sets the ecosystem on a new trajectory, keeping it in a state of constant, long-term flux.

Because the ecosystem will continue to change, monitoring must continue as well, said researchers, who note that the establishment of research plots immediately after the blast has made possible increasingly long-term studies. Said Peter Frenzen, the monument scientist for Mount St. Helens National Volcanic Monument: "Twenty years is really just the beginning. In some ways things are just beginning to get interesting."

–RICHARD A. LOVETT

Richard A. Lovett is a writer in Portland, Oregon.