Salt-loving algae wipe out fish in Appalachian stream

A salt-loving alga that killed tens of millions of fish in Texas has struck for the first time in an Appalachian stream that flows along the border of Pennsylvania and West Virginia. *Prymnesium parvum* or "golden algae" caused the sudden death of thousands of fish, mussels, and salamanders in early September along some 30 miles of Dunkard Creek. University and government scientists fear the disaster could presage further kills in the region. Streams at risk due to high concentrations of total dissolved solids (TDS) include portions of the northern branch of the Potomac River and 20 other streams in West Virginia, according to state scientists. Pennsylvania, Maryland, Virginia, and Kentucky also have many vulnerable rivers and streams, according to U.S. EPA scientists.

Dunkard Creek is a tributary to the Monongahela River, where last year high TDS levels fouled industrial equipment and ruined the taste of drinking water. Faced with projected increases in TDS as a result of the burgeoning and water-intensive natural gas hydraulic fracturing activity at the Marcellus Formation, Pennsylvania Department of Environmental Protection (PA DEP) recently proposed TDS standards for end-of-pipe discharges of 500 parts per million (ppm) TDS and 250 ppm each for sulfate and chloride.

Despite historically high TDS levels, the creek was a good fishing stream with small mouth bass, muskie, mussels, and salamanders, according to biologist Frank Jernejcic with the West Virginia Department of Natural Resources. In just a few days the algal bloom wiped out the creek's 18 species of fish and 14 species of freshwater mussels—the most diverse population of mussels in the Monongahela basin. "This is the worst fish kill I've experienced in 21 years in West Virginia," says Paul Ziemkiewicz, director of the Water Research Institute at West Virginia University.

Relatively high levels of sulfate and other dissolved salts have been common in Dunkard Creek over the past 10 years as a result of active and abandoned coal mine discharges, according to West Virginia monitoring data. But immediately before the bloom, chloride (300 ppm), sodium (>3000 ppm), TDS (9500 ppm), and electrical conductivity (>50,000 microsiemens per centimeter) all skyrocketed to unprecedented levels, prompting biologists to initially blame the chemical contamination for the aquatic devastation.

FRANK JERNEJCIC, WVDNR

Muskies are among the over 16 species of fish killed by the golden algae bloom on Dunkard Creek.

Now that the algae have been identified as the immediate cause of the fish kills, biologists wonder if the soaring salt levels somehow initiated the bloom. If so, there is evidence that Dunkard Creek is not alone in recently receiving record high chloride, associated with hydraulic fracturing or coal-bed methane wastewaters, not coal mine water, according to Ziemkiewicz. Using water monitoring and stream flow data, he calculated chemical loadings to the Monongahela and its tributaries. "Our mass balances can account for most of the sulfate but not the sodium and chloride," he says. "Concentrations of sodium and chloride were much higher than usual in Dunkard Creek during the fish kill—but even these high levels do not account for the loads in the main stem of the Monongahela River. We are missing major sources of those ions" he says. It is not currently possible to track the fate of hydraulic fracturing wastewater because, unlike coal mine discharges, it is not subject to permitted discharge controls under the Clean Water Act.

Midas touch

First identified in the 1930s, *P. parvum* is a microscopic flagellated organism that caused massive fish kills in the Sea of Galilee and in Israeli fish farms in the 1950s. Toxic blooms have also occurred in brackish waters in Europe as far north as Scandinavia and in China. The algae thrive in naturally brackish water typical of rivers and reservoirs in East Texas, Oklahoma, and Wyoming. Since the first documented fish kill in Texas in 1985, when more than 100,000 fish died in the Pecos River, the organism has killed more than 18 million fish valued at more than $7 million. In 2001, *P. parvum* killed the entire year's production of striped bass in Texas's Dundee State Fish Hatchery.

P. parvum's numbers usually remain low. But sometimes it rapidly reproduces with blooms that give the affected water a golden color. In Texas, blooms usually occur during the cooler months when the alga seems to have an advantage over other algae that grow best in warm waters.

The algae's toxins do not threaten humans, livestock, or wild animals. But the algal toxins break gill membranes so that unwanted chemicals, in particular calcium, pour in, says James Grover, a biologist at the University of Texas Arlington. "The cells fill up with calcium and explode," he says.

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The exact conditions that bring on an algal bloom are unknown, "That's the $64,000 question," says biologist Carmelo Tomas at the University of North Carolina Wilmington. "Studies have looked at nitrogen, vitamins, and trace metals, but these present a confusing story," he adds.

Texas's experience suggests that the algae need an ecological opportunity, according to Luci Cook-Hildreth, Golden Alga Coordinator with the Texas Parks and Wildlife Department. In Texas, blooms occur mainly in the winter months. "When temperatures cool down, that knocks back other algae. Then if we have a couple of clear sunny days, that's when we tend to get a bloom," she says. Ziemkiewicz says conditions were similar on Dunkard Creek just before the bloom.

Many streams vulnerable

West Virginia estimates that 21 streams could be at risk, based on having electrical conductivities greater than 1500 microsiemens per centimeter, which converts to about 750 to 1000 ppm TDS. This is a good preliminary assessment, says Grover. In Texas, blooms appear to require water with at least 500 to 1000 ppm TDS. "Specific ions are not crucial," says Grover, "but I get the impression that the more calcium in the mix, the better it grows," he says. Calcium also enhances the toxicity.

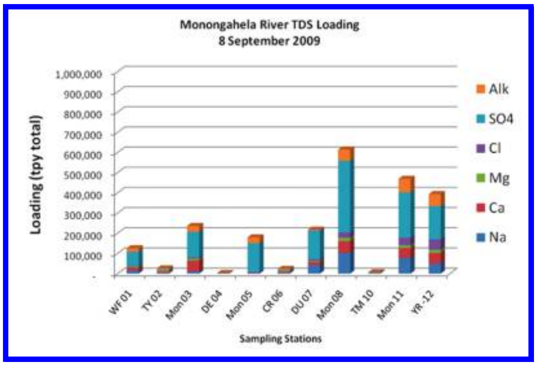
Blooms are not as toxic in slightly acidic water. "We think this is because there are ionizable groups on the toxin, so that the toxin becomes more potent as pH rises," Grover says. "There's a lot we don't know, but I believe that we know enough about the overall salinity and the role of calcium and pH to offer guidance, and West Virginia's on the right track."

Blooms can occur when surface water temperatures are as low as 12 °C.

They are unpredictable, but Grover, who is trying to develop a predictive model for *P. parvum*, believes this may be due to variable rainfall. "If we have a few wet months, the higher flow flushes out the algae. I think that's why it comes and goes," he says.

Fresh water

The algae's need for high TDS suggests a control measure in the Appalachians because, unlike East Texas, the high TDS is a man-made problem, according to Tomas. He notes that in 2001, a North Carolina striped bass business excavated and filled acres of ponds with artisanal well water. The bass did not grow well because the water was too soft. So the fish farmer changed the ponds to brackish water with TDS of about 4 parts per thousand. The fish thrived at first, but soon they died as a result of a *P. parvum* bloom. It wasn't until the fish farm went back to very low salinity water that the cycle of algal blooms ended.



USGS-FUNDED STUDY BY PAUL ZIEMKIEWICZ

Loading data suggest dumping of hydraulic fracturing waste water. Chloride and sodium loadings in Dunkard Creek (DU 07) can't account for loadings in the Monongahela River downstream (Mon 08). Other tributaries (YR-12) also have high loadings despite a lack of known sources.

The case study makes it clear that a switch from water high in TDS to low TDS water can prevent the algae from blooming, but the lower bound for the TDS is unknown. Pennsylvania's proposed discharge standards of 500 ppm TDS and 250 ppm each for sulfate and chloride would appear to keep the salinity below levels likely to cause an outbreak.

Hitching a ride

In early November, scientists found *P. parvum* in another stream close to Dunkard Creek. While some workers are extending this quest, others are trying to explain how a salt-loving organism common in East Texas and coastal environments found its way north of the Mason−Dixon line. Sea birds such as seagulls could have transported the algae, but many wonder whether *P. parvum* could have hitched a ride in a water tanker truck or other drilling equipment that has moved from the fields of the Barnett Shale in East Texas to the Marcellus Shale in Appalachia. "The movement of water in tankers for coastal species has been shown to be a powerful way for alien species to invade," says Grover. "Cells or spores can survive in ships' ballast water. I don't know anybody who has looked at smaller tanker trucks or other such equipment, but it must be a consideration," he says. A recent New York state environmental impact study likewise sounds a now somewhat prescient warning: "potential mechanisms for the possible transfer of invasive aquatic species may include trucks, hoses, pipelines, and other equipment used for water withdrawal and transport," the report states. Residents who live along Dunkard Creek have seen drilling tankers remove water from the creek; this suggests the physical possibility of such a transfer. In Pennsylvania, such withdrawals do not require a permit as long as they are small in comparison to the volume of the stream, according to PA DEP spokesperson Helen Humphreys.

Genetic studies are currently under way to see if *P. parvum* from Dunkard Creek is genetically similar to strains from Texas. "The genetic studies may show that there is a lot of variability. This might suggest multiple introductions from multiple sources," says Grover. "But if the Dunkard Creek strain matches those from Texas, well maybe that looks a little fishy," he says sadly.

—REBECCA RENNER