Blooming nightmare. Scooping *Microcystis* at Taihu.

ECOLOGY

China Aims to Turn Tide Against Toxic Lake Pollution

TAIHU, CHINA—The hut perched at the end of a wooden pier looks like a hermit's lonely retreat. Inside, however, the room is alive with the hum of instruments monitoring Taihu's vital signs: chlorophyll and nutrients in the water column, carbon dioxide and methane wafting from the surface. "Before, we had to stand on a platform in the lake and manually take measurements. Not safe in a thunderstorm," says Qin Boqiang, an ecologist at Nanjing Institute of Geography and Limnology of the Chinese Academy of Sciences (NIGLAS). Now data stream to shore via a wireless network.

The lab-on-a-lake allows Qin and his colleagues to keep a round-the-clock vigil on their gravely ill subject. Over the past 3 decades, industrial effluents, farm runoff, and sewage have besieged Taihu, China's third largest freshwater lake, knocking its ecosystem out of balance. The assault has paved the way for a nasty blue-green alga, *Microcystis aeruginosa*. Every summer, when the air here in Jiangsu Province turns muggy and lake surface temperatures exceed 23°C, the cyanobacterium blooms with a vengeance, turning sections of Taihu pea green.

Microcystis is more than just an eyesore. It produces toxins that can damage the liver, intestines, and nervous system. In May 2007, an algae outbreak sparked by unusually warm weather overwhelmed a water works that supplies Wuxi city on Taihu's northern shore, leaving more than 2 million people without drinking water for a week (*Science*, 31 August 2007, p. 1166). "It was a monster bloom," says Hans Paerl, an aquatic ecologist at the University of North Carolina, Chapel Hill. The crisis transformed Taihu into a poster child for the environmental consequences of the country's rapid economic growth. "It's important to restore the lake's ecosystem—for China," says Zheng Binghui, vice president of the Chinese Research Academy of Environmental Sciences in Beijing. Local officials vowed to clean up the mess.

Four years later, efforts to heal Taihu are showing results. To cut down on pollution and the massive influx of nitrogen and phosphorus, authorities forced hundreds of small chemical and manufacturing plants near Taihu to close or relocate, and they instituted strict controls on effluents from factories that were permitted to stay. The province has erected sewage treatment facilities on Taihu tributaries and dredges the lake to remove nutrient-rich sediments. As a result, nutrient concentrations are beginning to taper off. "Water quality is no longer deteriorating," Qin says. "It hasn't got any worse," adds Paerl, who is working with NIGLAS to devise a nutrient management strategy aimed at curbing blooms. "But we haven't turned the corner yet."

Restoring Taihu to a truly healthy state will be a challenge akin to ongoing efforts to bring polluted Lake Erie back from the near-dead. At Taihu, China's environment ministry plans to allot $80 million to develop management strategies and cleanup technology over the next 5 years, a sum that local authorities are expected to match. The key, Qin says, will be pinpointing sources of nitrogen and phosphorus and stemming their flow into the lake.

Success at Taihu could have a global payoff. "*Microcystis* has exploded around the world," Paerl says. Regional climate changes appear to be catalyzing the algal surge by raising average water surface temperatures and increasing water-column stratification—manna to bloom-forming cyanobacteria. "These effects are playing right into the cyanobacterial playbook," Paerl says. Farm practices are abetting the alga's rise. "We're seeing a greater-than-ever application of fertilizers in various watersheds. Unfortunately, many of these fertilizers don't make it into grains and corn but into the water instead," says Steven Wilhelm, a microbiologist at the University of Tennessee, Knoxville. "We have shaped the environment over the last few decades in a way that could favor blooms."

As a result, from Lake Okeechobee in the United States to Lake Victoria in Africa and Japan's largest lakes, Biwa and Kasumigaura, algal blooms threaten drinking water supplies and the sustainability of freshwater ecosystems. In the United States alone, cyanobacterial blooms inflict about $2 billion a year in losses from water made unfit for recreation, drinking, or agriculture, according to a 2009 analysis in *Environmental Science & Technology*.

Under attack

With a maximum depth of only 3 meters, turbid Taihu is prone to eutrophication, or nutrient buildup. Starting in the 1980s, its ecosystem began to shift from one dominated by diatoms, a benign and desirable kind of phytoplankton, to one in which cyanobacteria now reign supreme. By the late 1990s, *Microcystis* blooms were a regular summer phenomenon. When mats form, other organisms are squeezed out.

As macrophytes such as lotuses and water chestnuts began to lose ground a decade ago, water managers tried to reintroduce cultivated macrophytes. "They thought it would clean the lake," Qin says, because floating macrophytes impede wind-driven algae from clumping together. NIGLAS scientists curtained off sections of the lake and seeded them with macrophytes; the plants flourished. Outside the experimental boundaries, however, the attempt at a natural antidote failed. "When the water is polluted, macrophytes don't grow well," Qin says. "We understood that we have to clean the lake first."

Before that lesson could sink in, the 2007 drinking water emergency thrust Taihu into the national spotlight. At the time, Wuxi was drawing 80% of its drinking water from the lake. That May, the algal mats were so thick, and the bloom so pervasive, that near-shore masses sank and rotted. "Decaying algae has a very strong smell, like dead fish," Qin says. Wuxi residents complained that their tap water stank.

The crisis was a wake-up call. One immediate fix was to extend the intake pipe from just offshore, where prevailing winds tend to sweep the algal mats, to the center of the lake. To wean itself off its Taihu dependency, Wuxi

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now pumps half of its drinking water from the Yangtze. And Jiangsu's government launched measures, such as moving chemical plants, to reduce nutrient loading.

Major gains may only come from a clearer picture of the sources of nutrients washing into Taihu. "We need to have basic data in order to restore the lake," Qin says. In tributaries and more than 100 canals that feed into Taihu, "water quality is quite bad," says NIGLAS biochemist Zhu Guangwei. Nitrogen spikes in the spring, after tea farmers cover plots in manure. NIGLAS recently found that about a quarter of Taihu's nitrogen inputs settle from the air, most likely from vehicle emissions, Qin says.

Authorities are mulling whether to create a buffer zone along the shore several hundred meters in width, where farm fields and villages would be converted into wetlands and parks. In the densely populated and wealthy region, a relocation program would cost a fortune, Qin says. But it would give the embattled lake some breathing space.

One scientific component of the 5-year plan is a renewed drive to resuscitate macrophytes, including curly-leaf pondweed (*Potamogeton crispus*) and whorl-leaf watermilfoil (*Myriophyllum verticillatum*). NIGLAS researchers also intend to develop methods to forecast when blooms break down and isolate patches of decay to stem the diffusion of toxins in the water column.

Striking back. Qin Boqiang is experimenting with macrophytes in enclosures (*background*) at Taihu.

A winning strategy is "not going to be easy," says Wilhelm, who visited Taihu this summer: It may require both quick fixes like dredging and dogged long-term efforts to curtail nutrient loading. Some experts have mooted the use of chemicals to precipitate phosphorus out of the water column, but that approach may not work in a large, shallow lake frequently buffeted by strong winds that stir up sediments, Paerl says. *Microcystis* exploits these conditions, feeding on suspended nutrients. "The alga is clever," Paerl says. "It really is the cockroach of lakes."

Zhu for one is optimistic that managers can bring the beast to heel. In the next 5 to 10 years, he says, "we'll see a big improvement." He anticipates that both the area and duration of *Microcystis* blooms will steadily shrink. Eliminating blooms—and restoring Taihu's natural order—is a taller order. "It takes several decades for a system to get as bad as this one has become," Paerl says. "We can't expect overnight solutions." **–RICHARD STONE**

HUMAN SUBJECTS RESEARCH

Panel Blasts Ethics, Science of 1940s Guatemala Studies

An exhaustive high-level review of unethical syphilis experiments conducted in Guatemala by U.S. researchers in the 1940s has found little to redeem the work or its lead researcher. The Presidential Commission for the Study of Bioethical Issues found that the study was shoddy scientifically and did not meet ethical standards at the time.

The 1946–48 experiments, in which U.S. Public Health Service researcher John Cutler deliberately infected hundreds of Guatemalan soldiers, prisoners, and mental health patients with sexually transmitted diseases, were first revealed by a Wellesley College historian last October (*Science*, 8 October 2010, p. 160). They have been compared to the infamous Tuskegee, Alabama, study in which African Americans with syphilis were observed but not treated. Cutler, who died in 2003, was also involved in that study from 1932 to 1972. President Barack Obama asked his bioethics commission to investigate last fall.

The commission's staff spent 9 months digging through and reviewing more than 125,000 archival documents. The commission conducted "a careful and unvarnished ethical analysis" of what happened, said chair Amy Gutmann, president of the University of Pennsylvania, at a meeting this week.

The panel found a compelling context for the experiments: Sexually transmitted diseases were rampant among returning World War II veterans. Soldiers at risk were told to apply various prophylactic treatments, and Cutler wanted to find out if penicillin worked better. He and others took blood and other fluid samples, including spinal taps, from more than 5000 patients in Guatemala, without their consent. An overlapping group of more than 1300 patients were exposed to syphilis, gonorrhea, or chancroid. Fewer than 700 got some form of treatment.

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>
> **—AMY GUTMANN, PRESIDENTIAL BIOETHICS COMMISSION**

The Guatemala project violated ethical norms of the day, the panel found, after comparing it with a similar experiment performed by some of the same researchers at a federal prison in Indiana a few years earlier. There, prisoners were also exposed to gonorrhea, but only after they had volunteered and given informed consent. In addition, community standards were emerging: In 1947, U.S. physicians published the Nuremberg Code requiring patients' consent—a response to Nazi experiments.

The commission also found many problems with study methodology, including haphazard note-taking and illogical timing of experiments. For example, serological studies to determine baseline disease rates in the population were conducted after the treatment studies had begun. Little was published. "It was bad science," Nelson Michael of the Walter Reed Army Institute of Research in Silver Spring, Maryland, concludes. The commission blames this in part on Cutler's inexperience but also held him and his supervisor, John Maloney, responsible for burying their reports.

Although the Guatemala experiments would not happen under today's rules, "we should be ever vigilant to ensure that such reprehensible exploitation of our fellow human beings is never repeated," Gutmann said. The commission is following up with a review of standards for protecting research subjects in the United States and abroad.

An international subcommittee appointed by the panel has found several areas for improvement, including a need to engage with local communities, improve study transparency, and ensure ethics training of researchers and ethics reviewers abroad. The subcommittee's findings will be published in the *Federal Register* for comment and fed into a final report from the bioethics commission in December. **–JOCELYN KAISER**

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