BENDING TO THE WATER'S WILL

In flood-prone Bangladesh, resilience can mean letting water have its way

By **Warren Cornwall**, *on Polder 32 in Bangladesh; Photography by* **Tanmoy Bhaduri**

For Jaharul Sardar, a rice farmer in rural Bangladesh, the perils of living behind a wall hit home one cloudy May afternoon in 2009. Sardar was standing beside his fields when he heard neighbors cry out in alarm. A black hill of seawater was sweeping toward him. Sardar's wife and 5-year-old son clambered atop the embankment that stands guard over his mud-floored house. Instead of joining them, he dashed inside to rescue a suitcase stuffed with cash and property records.

Within seconds, waves slammed into the house. Sardar was trapped. Water pushed the structure, with him inside it, into an adjacent pond. His wife pulled him to safety, soaked but alive.

For Sardar, relief was short-lived. That day marked the beginning of fierce floods. Each day the tide poured in through the breached wall, drowning fields and homes in saltwater, and then withdrew and left a blanket of mud. "During high tide it was all underwater. And during low tide it was like [a] desert," Sardar says.

The 4-meter-high earthen wall that failed dated from the 1960s. It encircles 80 square kilometers of land to create a massive "polder"—an artificial island surrounded by the vast tidal rivers that extend like thick ten-

Villagers cluster on Polder 32, an artificial island in southwest Bangladesh with an uncertain future.

drils from the nearby Bay of Bengal. At 66, Sardar remembers conditions before the wall, when flooding during very high tides was the norm here. Until that fateful day in 2009, the flooding appeared to be banished.

Bangladesh, a vast river delta that barely rises above the sea at the best of times, is buffeted by natural forces including flooding rivers and cyclones blowing in from the bay. Over decades, the country has developed defenses: warning systems, storm shelters, salt-resistant crops, and 139 polders near the coast—a 5700-kilometer network of walls to protect farmland from inundation. But humanmade infrastructure is not infallible and can cause problems of its own. That's starkly apparent across the country's polders, which have disrupted a fragile standoff between water and land and are now straining to hold back the water. As climate change compounds that threat with rising seas and stronger storms, Bangladeshis who have spent years building barricades are considering what was once unthinkable: letting the water in. It's resilience by bending, not resisting. And it's tougher to do than it sounds.

Other countries are trying similar approaches. Vietnam recently adopted plans to allow more flooding in the upper reaches of the Mekong delta. The Netherlands, renowned for building some of the world's most sophisticated sea walls, is adapting suburbs for controlled river flooding. On the other end of the spectrum sits Indonesia, which is planning a $40 billion, 40-kilometer-long sea wall to shield its capital city, Jakarta, from the Java Sea.

Here in a country the size of Iowa that's home to 165 million people, experiments in resilience underscore the challenges of rearranging a crowded landscape. "You can't remove the polders now," says Anisul Haque, a hydraulic modeler at the Bangladesh University of Engineering and Technology (BUET) in Dhaka who studies coastal flooding. "So what can you do?"

Polder 32 resident Jaharul Sardar, who narrowly escaped a 2009 flood, remembers when the walls ringing his home kept him safe.

RIVERS ARE THE MIDWIVES of Bangladesh. The Ganges and Brahmaputra pour from the Himalayas and converge with the Meghna River to form the world's fourth largest drainage, which flows into the Bay of Bengal. Monsoon rains routinely put a quarter of the country underwater. The flooding brings hardship, but it also nurtures the rice that feeds one of the most densely populated nations on Earth.

The country itself is born from those rivers. An estimated 1 billion tons of sand and silt flow downstream every year and settles in the delta, counteracting relentless erosion. Geologically, Bangladesh is a giant sandbox, 90 meters deep in places.

Ainun Nishat knows those rivers with an intimacy earned by spending 4 decades studying them. Sitting in his third-floor office at BRAC University's Centre for Climate Change and Environmental Research in Dhaka, the engineer describes how good intentions have brought unexpected consequences.

Polders—the name is borrowed from the Dutch, who used a similar strategy to carve farmland from marshes—were first built in Bangladesh in the 1960s. But although polders allow more intensive farming, Nishat says, "They are also a problem." The walls impede the natural movement of water and sediment. Rivers now funneled between artificial embankments are filling with silt. Land inside the polders, starved of new soil that would otherwise flow in, is sinking. Polders are turning into bathtubs that, if something goes wrong, can fill with water.

Meanwhile, sea level is projected to rise 0.4 to 1.5 meters on the Bangladesh coast by 2100. Episodes of extremely high water driven by storms and tides, which today occur once a decade, will probably happen

NATURE'S STRATEGIES

Squirrels with a rainy day fund

Scurrying around the South Dakota prairie, 13-lined ground squirrels (pictured, right) mark the approach of winter by bingeing. By the time a squirrel holes up to hibernate, its weight will have soared by about 40%, thanks to extra fat that will tide the creature over until spring.

During droughts, migrations, bleak winters, and other challenges, organisms often face times when resources are scarce. To get by, the ground squirrel, like many other creatures, stockpiles resources to use later. It can gain more than 2% of its body weight in a single day as it gorges on seeds, grasshoppers, and other delicacies.

But the tactic has downsides. A roly-poly rodent is easier prey for a hawk or coyote. The rainy day fund also can run out prematurely. So once a squirrel is nice and tubby, it enters hibernation, slashing its energy expenditure by 90%. Its body temperature drops to just above freezing and its heart rate falls to as low as 5 beats per minute, down from the usual 350 to 400.

Packing on the fat requires metabolic and behavioral adjustments. But somehow, the squirrel dodges the health problems that plague obese people. Although it develops some of the metabolic defects of type 2 diabetes, the animal isn't sick. And by spring, it is lean and spry and ready to begin the cycle again. —*Mitch Leslie*

PHOTOS: (TOP TO BOTTOM) TANMOY BHADURI; GRACHEVA LAB

three to 15 times every year at the end of the century, according to a 2015 study by U.K. and Bangladeshi researchers. That trend will put the polders and their inhabitants at even greater risk.

The devastation of Sardar's polder, Polder 32, starkly illustrates the dangers posed by that confluence of climate change and decades of hydraulic tinkering. That day in 2009, a wave of water originating from nearby Cyclone Aila combined with strong currents to burst through embankments on several polders. The disaster left more than 150 dead and $270 million in damages in Bangladesh.

Many believed the answer was to strengthen the polders. In 2013, the World Bank committed $400 million to raise embankments on 17 polders that are home to nearly 800,000 people. It's a first step in a push by the Bangladeshi government to build up the entire polder system with an eye toward rising seas.

What Steve Goodbred, a coastal geologist at Vanderbilt University in Nashville, saw when he visited Polder 32 after the storm pointed to a different approach. Goodbred and a research team found that land inside the polder was more than a meter below the average high tide in the area. As long as the walls held up, the sinking went largely unremarked upon. But the cyclone laid bare the risks. "It was, 'Wow, no wonder the flooding was so bad,'" says Goodbred, who has spent the past 2 decades studying the Bangladesh delta.

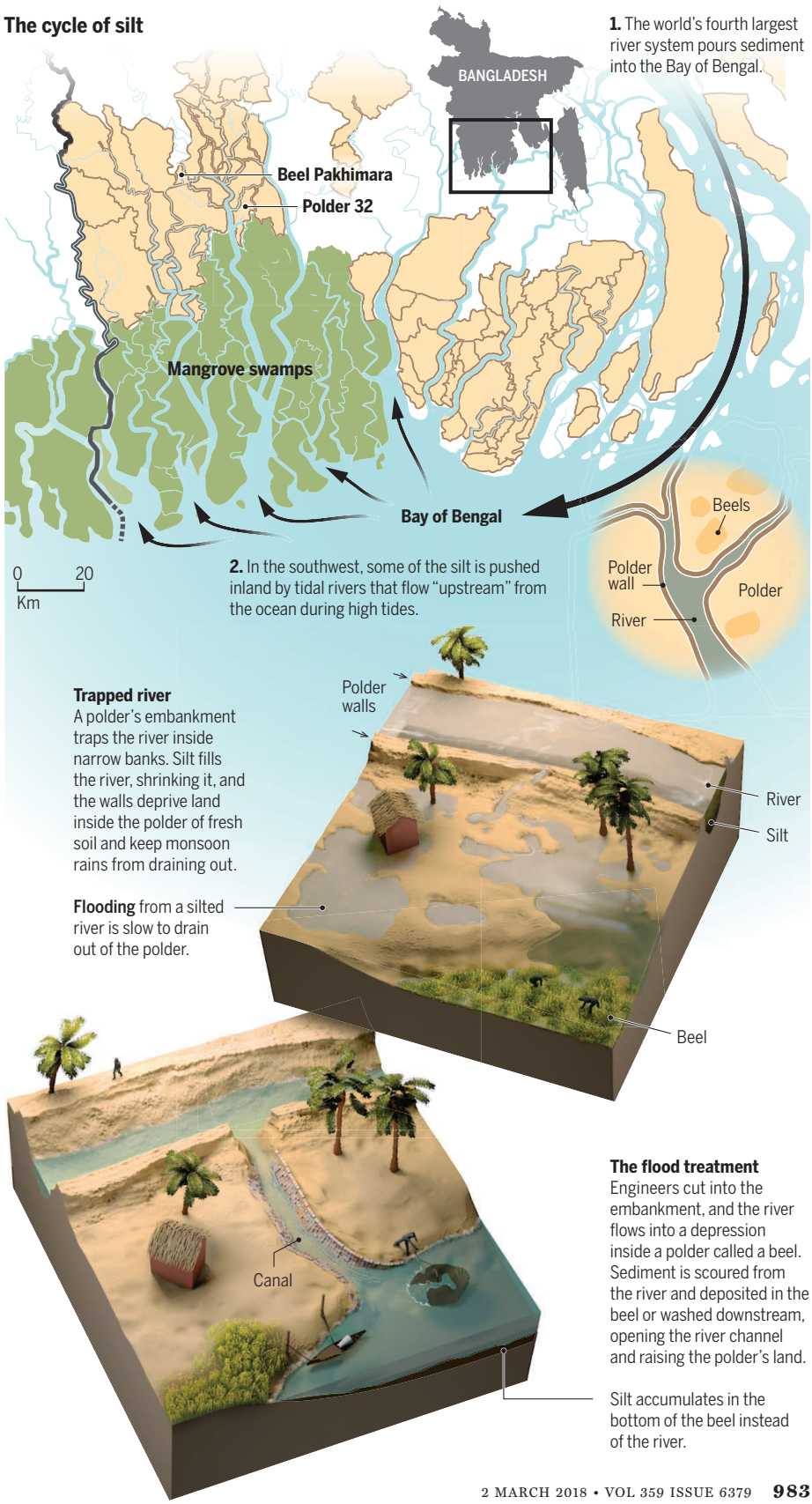
However, Goodbred also found cause for optimism. Land just outside the polder was 10 centimeters above the typical high tide, suggesting that, without human intervention, natural sediment deposition would keep the land above all but the highest tides. Furthermore, the disastrous flooding here had an upside, delivering enough new silt to raise land inside the walls more than a third of a meter on average.

That outcome led Goodbred to suggest letting some water in. In the short term, controlled flooding into the polders might be painful. In the long run, it could elevate land and minimize damage from future breaches. In a world of rising sea levels and bigger storms, Goodbred says, "I think that has to be a part of any long-term solution."

IT'S A SEDUCTIVE IDEA. It's also not a popular one for many who would have to live with the consequences, including government officials. "We don't need to raise the land. Farmers are not demanding it," says Abdul Hannan, the top engineer in this region for the Bangladesh Water Development Board, the powerful government agency that manages the country's water.

Water meets land in Bangladesh

Many Bangladeshis live on artificial islands called polders, behind walls built to protect the low-lying islands from floods. But the polders disrupt sediment deposits and face climate change pressures, and it's harder than ever to keep water out. Residents are considering new ways to protect the polders and their land.



GRAPHIC: J. YOU AND V. ALTOUNIAN/*SCIENCE*

A woman walks by a canal linking the Kobadak River to a polder. Connecting the canal and the river causes flooding in one place that might protect land elsewhere.

PHOTO: TANMOY BHADURI

Yet about 30 kilometers inland, farmers spurred an experiment to do just that. It's much like the prescription Goodbred offered—use controlled flooding to raise sunken land and drain polders—but this experiment began almost by accident in the early 1990s.

These inland polders are designed to protect against flooding by seawater driven far up river channels during high tides. After the embankments were built, those rivers, with smaller, slower currents than rivers closer to the coast, started clogging with silt that would otherwise have settled on land. Meanwhile, the polders began to sink. After monsoon rains, water in the polders failed to drain through small canals into surrounding, now sluggish, rivers. Farms and towns inside stewed in stagnant water for months.

Local ingenuity and desperation prompted farmers on two river systems in southwest Bangladesh to cut gaps in embankments to open the polders to the river. The government cracked down with arrests. Then, something unexpected happened—exactly the outcome Goodbred later saw at Polder 32. Within a few years, the land inside the inland polders had risen a meter or more. The rivers grew deeper. Waterlogging eased.

Since then, government officials have tried to replicate the success of those first improvised projects. The latest test for what's known as "tidal river management," or TRM, began in 2015. A construction crew cut through the embankment of a polder lining the Kobadak River. Workers then dug a canal joining the river outside the polder to a 660-hectare depression inside it—a wetland known as a beel.

Visit today and the experiment's effects are evident. Parts of the beel, called Beel Pakhimara, have gained half a meter of fresh land. The river runs faster, as sediment is deposited in the beel instead of the riverbed. As the main river channel grows deeper, water is once again draining from nearby polders.

The endangered Ganges River dolphin has put in appearances since the flow returned, says Jahin Shams Sakkhar, an official with Uttaran, a local organization that has campaigned for projects like this one. "The more open it is, the more good it is for nature and for people," he says.

Yet the filling of the beel hasn't gone entirely as planned, partly because "so far, the whole TRM process has been based on assumptions," says Shah Alam Khan, a civil engineer at BUET, who is helping lead a Dutch-funded study of the Kobadak River project. The polder's land rose unevenly, with the area near the canal benefiting the most. Engineers are still deciphering sediment dynamics and considering how best to direct flooding, Khan says.

THE GREATEST CHALLENGE to opening the polders isn't the engineering, it's the people. Can some be persuaded to accept flooding on their land for years so that others can live flood-free?

Winners and losers are scattered around Beel Pakhimara. While farmers in nearby towns gather the rice harvest in golden fields now free from waterlogging, the beel is a desolate land of gray and pale green. Those who once farmed it have seen their rice paddies, fish farms, and ponds turn into a dumping ground for river sediment. It will remain that way until the canal is closed in approximately 2020, when the beel has filled with sediment and can be returned to cultivation.

Outside a small compound of brick and mud huts tucked against the embankment, 35-year-old Hanif Sardar (no relation to Jaharul) has little good to say about the project that's supposed to help rescue his country's land. He tried to get paid for the fifth of a hectare of land in the beel where he once grew rice that fed his family, he explains. "The government official says, 'Leave the application, something will happen. Don't worry.' But nothing happened," he says bitterly. "All the big landowners got the money. But the small landowners are not getting compensation."

The waterlogging that left a third of a meter of water in his yard for months each year ended in 2016. But that's outweighed by the family's loss of farmland. "The disadvantage is more," says Hanif's uncle, Amzad Sardar, "and the advantage is few."

To understand why some citizens turn against TRM projects, Mahmuda Mutahara, a Bangladeshi who recently earned her Ph.D., has spent much of the past 5 years traversing the region's pothole-riddled roads, often on the back of a motorcycle. Questioning residents, government officials, and others, she found government agencies disconnected from locals, spawning distrust and anger that have derailed controlled flooding attempts, sometimes spectacularly.

Government water officials "are not so much interested to talk to the local people," to learn about their wishes and explain how, in the long run, they might benefit, says Mutahara, who lives in Dhaka and studied environmental science at Wageningen University in the Netherlands. "That is the problem." To illustrate her point, Mutahara shares a story that for her is emblematic of the tangled social forces that make such work fraught with tensions.

Over the past decade, a rotating series of TRM projects on the nearby Hari River have repeatedly gone awry. Flooding in one beel dragged on years longer than planned. Farmers pressed for compensation for lost harvests. Fish-farming interests resisted the injection of fresh silt because it would fill their ponds. In 2012, a crowd rioted as government officials prepared to flood a beel there. The government suspended work and has yet to return.

Six years later, the Hari River problems remain, and so do the charred shells of three cars that rioters set on fire. "If, within the next 2 or 3 years, they do not do TRM upstream, the river will be silted up completely," Mutahara says.

The government has tried to learn from its mistakes, says Probir Kumar Goshwami, lead engineer at the Bangladesh Water Development Board's office in nearby Jessore. Last year, the government set up a temporary office near Beel Pakhimara where people could file for compensation. Water management officials are meeting more with locals. This year, the water agency plans to resume work on the beel at the center of the 2012 riot.

Despite some government resistance to TRM, Goshwami says there's no better alternative for those walled-off villages. "The tidal river management is the only solution."

Could controlled flooding be exported downstream to places like Polder 32? The chronic, low-level flooding on the Kobadak River differs from the threat of catastrophic, storm-induced flooding closer to the sea. And yet both places have something in common: a need to build up land.

As of now, no specific plan exists to bend to the water's will. Even a sort of "TRM lite"—a compartmentalized flooding in which small sections of polders are opened to raise elevation bit by bit—hasn't gained traction, says Haque, who has used computer models to study solutions to coastal vulnerability. Residents would have to be persuaded to live for years with flooded land. Reluctant government officials would need to embrace the approach. "This is a social problem," he says.

On Polder 32, the fields are dry today. It was one of the first places to get new, higher walls under the World Bank initiative. The breaches in the dike were closed in 2011.

Jaharul Sardar's view across the water, however, is a reminder that walls cannot erase risk. The land inside the polder is visibly lower than the shoreline outside it. But as he strolls barefoot atop the freshly rebuilt embankment, he feels safe for now. "If we have good embankments and cyclone shelters," he says, "we can survive." ■

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NATURE'S STRATEGIES

A plant that stands and fights

Unlike those of us on legs, plants can't run away from what they don't like—yet they show remarkable resilience when under attack. Consider how the wild tobacco plant (*Nicotiana attenuata*, pictured above), a meter-high native of North America, protects itself from hungry insects. The plant senses the amino acid compounds in a caterpillar's saliva and responds with an alarm signal—a hydraulic or electrical pulse through its stems and leaves. Within minutes, the plant's cells rev up their production of nicotine, a poison that interferes with an animal's muscle function. When attacked, a single wild tobacco leaf can pack in a half a cigarette carton's worth of nicotine. But some caterpillars, such as hawkmoths, have evolved a way to pass that poison through their gut instead of absorbing it, forcing wild tobacco to unearth new countermeasures. The plant produces compounds that inhibit digestion and make the caterpillar sluggish, as well as abrasives that wear down the attacker's mouthparts. At the same time, the plant calls in help by emitting a scent that attracts ground-dwelling bugs and other caterpillar eaters, and then puts up chemical signposts to guide those predators to their already sluggish prey. Finally, a plant under siege redirects its resources, putting off flowering and growth until the caterpillars are gone. Amazingly, all of this is orchestrated not by a centralized brain, but by decision-making cells scattered throughout the plant.
—Elizabeth Pennisi

Bending to the water's will

Warren Cornwall

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