

SUSTAINABILITY

How a small group of visionaries are trying to feed China—and save the world's oceans

*By Erik Vance*

# Fishing *for* Billions

**NETTING** partitions Liangzi Lake into zones cultivated by two companies. Greater productivity from freshwater fish farms is needed to ease overfishing at sea.

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**I**N JANUARY 2007 NGUYỄN PHÚ WAS PREPPING HIS SMALL BOAT FOR WHAT APPEARED to be just another day of fishing for octopus off the Vietnamese coast. Soon after he headed out to sea, several Chinese boats appeared on the horizon. Phú thought momentarily about fleeing but knew he would not get far. When the gunships sidled up to his boat, he and his crew put up no resistance. “We don’t mess with the Chinese,” he says. “We just go into this position”—he crouches down with his hands above his head—“and we pray to God that we can suffer this.”

He claims Chinese soldiers took him and his crew to a jail on a nearby island and confiscated his boat. Phú spent more than a month in a cramped cell and received daily beatings, he and his crew say. Then he was let go; no trial, no judge, no reason given. The military had caught him and released him, just like a fish.

Phú’s story, which he told me through an interpreter in August 2014, fits a well-documented pattern of grandstanding by China in Pacific waters near Asia in recent years. Fijian tuna fishers say that Chinese captains refuse to acknowledge catch limits around their islands. Chinese poaching in Japan’s marine parks has strained already tense relations between those countries. The Philippines is escalating its military presence near a few scattered shoals that Chinese fishing boats now patrol off its coast. China claims that the South China Sea has been part of its territory for hundreds of years.

What is not in dispute is the basic fact that China is hungry for fish. As the nation’s standard of living rises, demand for seafood has soared. Per capita, the Chinese eat 50 percent more fish than Americans. The country’s 1.4 billion citizens eat more fish than those of the next 10 biggest countries combined.

To meet the growing demand, China in 2012 produced 57 million metric tons (tonnes) of fish from wild fisheries and fish farms—one third of the world’s total—according to the United Nations Food and Agriculture Organization. China currently has 700,000 fishing vessels that patrol waters around the globe. Its ships drag enormous cages along the ocean bottom and haul nets the size of football fields through the water. Other nations use similar techniques, but China surpasses even Japan and

the U.S. as the country most responsible for emptying the world’s fisheries.

As a result, many animals in popular dishes—sea cucumbers, sharks, abalone—are steadily declining around the world. Beyond symbolic gestures such as banning shark fin soup at official functions, the Chinese government has so far been reluctant to acknowledge the issue.

But some Chinese scientists and businesspeople, worried that modern fishing methods are depleting the world’s oceans faster than they can replenish themselves, are starting to tackle the problem. A handful of these visionaries are trying to reverse the trend by reinventing China’s aquaculture—from the thousands of small, freshwater farms still using ancient methods to massive industrial ocean farms.

Their goal is to transform the old, wasteful, polluting operations into a uniquely Chinese form of sustainable seafood while helping fish farmers, big and small, to prosper. They are hoping to appeal to the desire of Chinese consumers for fish that is clean and healthy to eat by presenting their aquaculture as a modern alternative to conventional practices. If the researchers and business leaders can find sustainable ways to fulfill demand for traditional favorites such as freshwater carp, they could go a long way to saving the world’s fisheries from collapse.

#### MANAGING THE OCEAN LIKE A FARM

THE WATERS of the fish farm around Zhangzi Island, near Korea, are cold. The chilly water here is said to produce the best seafood in the world. The particular cove I am preparing to enter is



**ZHANGZIDAO FARM** relies on ocean currents to move nutrients among different species. Farmers sort juvenile scallops before placing them in the sea (*below*), dive (*left*) to check growing sea cucumbers (*above, left*) and prepare big blocks made from recycled scallop shells (*above*) used to direct the currents.



famous because in 1972 its abalone was chosen for the banquet honoring then president Richard Nixon’s historic visit, which opened trade relations with China.

Today the air is warm, so my seven-millimeter-thick wet suit is stiflingly hot for the few minutes before I plop into the water, along with two guides and a photographer, like so many neoprene potatoes. My companions are fishers at Zhangzidao Group, a once traditional fish farming corporation that today is experimenting with a new idea. They are friendly enough but also seem a little suspicious. We are the first foreign journalists to tour the site.

As we descend into the dark water we see what looks like a common coastal ecosystem: grasses, kelp and wide, sandy stretches. Then I notice that the ocean floor is littered with sea cucumbers, bivalves and urchins—not hidden in nooks and crannies as one would expect but wandering out in the open. Immediately, the fishers begin plucking up sea creatures by hand like children on an Easter egg hunt.

This fish farm—if one can even call it that—uses a novel approach that replicates natural systems on a grand scale. Behind us, spanning this and every other cove, are endless lines of caged, baby scallops that will be dropped into the waters, where they will stay until they are big enough to be harvested by the men who are swimming next to me. Other than these, there are no cages or enclosures. There are also no fertilizers, artificial feeds or antibiotics.

“We use a model called IMTA,” says Liang Jun, the company’s chief scientist, “where the excrement from one species can be the nutrients for the other species.”

Integrated multitrophic aquaculture, or IMTA, is a broad concept that has appeared in various forms in countries that include Canada, Scotland, the U.S. and Norway. The idea is that having multiple species recycle one another’s excrement (or “nutrients”) decreases water pollution. Most conventional IMTA approaches take the form of a series of neighboring cages,

#### IN BRIEF

**China produces** one third of the world’s seafood, and it consumes more than the next 10 countries combined. Whether it can reinvent its freshwater and saltwater fish farms to lessen its

take from the sea will determine if the world’s fisheries survive or collapse. **A handful of scientists** and businesspeople are redesigning ocean aquaculture operations so that multiple spe-

cies recycle one another’s effluents, making the farms less polluting and more sustainable. They are trying to do the same with China’s thousands of large and small freshwater farms, which

supply 70 percent of the nation’s fish. **So far seafood raised** this way is expensive; costs will have to come down before Chinese consumers buy the products widely.

in which the occupants of each cage feed off the nutrients of another. For example, the most well-known IMTA project is in Canada's Bay of Fundy, which uses lined-up cages to pass nutrients, down current, from salmon to bivalves and kelp.

Zhangzidao takes a totally different tack, however. In essence, Zhangzi and several other islands act as de facto cages. Jun's team has carefully studied the movement of nutrients along the shores, occasionally building artificial reefs to redirect the currents that move them. Then they seed nutrient-rich parts of the islands with young scallops bred to thrive here while carefully removing their predators.

Naturally the waters become rich with a few select species. The company monitors key markers such as temperature, but mostly the animals are left to fend for themselves until divers systematically collect them. There is no bycatch—the wasteful scooping up of unwanted species—as in wild fishing, and little pollution. The company recycles its shells into concrete blocks for future reefs.

What really sets this project apart is its scale. “When they decide to have aquaculture in a bay, they go massively—something that would be impossible in the Western world,” says Thierry Chopin, a biologist at the University of New Brunswick, who is working on the Bay of Fundy project. “It’s completely different.”

The Bay of Fundy operation covers a few hectares and holds nine “mussel rafts” filtering effluent. In contrast, the Zhangzi Island ocean ranch is four times the size of Chicago. The Bay of Fundy produces around 200 tonnes of kelp every year and 300 to 400 tonnes of mussels. The islands around Zhangzi produce 60,000 tonnes of kelp, mostly as a by-product that is sold locally. The real money is in the 200 tonnes of sea urchins, 300 tonnes of oysters, 700 tonnes of sea snails, 2,000 tonnes of abalones and a whopping 50,000 tonnes of scallops raised a year. The operation is so productive that Zhangzidao recently created a fishing tourism business to catch the many fish that wander into the coves to snack on the thriving invertebrates.

Jun says this particular brand of aquaculture can only work at a very large size. “You have to have a system that is at least 100 square kilometers,” about the area of a small town, he says, to be economically viable. “And to farm something like this, you need lots of research into ocean dynamics.”

He spins his computer screen around to reveal a detailed map of the islands showing where nutrients concentrate and where yields are highest. Most of these factors are based on ocean currents, which Jun can fine-tune by dropping concrete blocks the size of refrigerators into the water to form the artificial reefs. He has lowered 20,000 such blocks into the sea.

Some Westerners argue that Zhangzidao is not truly using IMTA, because it does not grow or harvest finfish, whose excrement, in theory, would feed the invertebrates. They prefer a less technical term, such as “ocean ranch.” Either way, Zhangzidao is stunning in size and efficiency. Yet it is by no means perfect. According to a spokesperson, more than half of the ranch is too deep to harvest by hand, so fishers still use trawls—heavy, stiff five-meter-wide nets that are dragged along the ocean bottom



**FARMERS** at Luhu Lake feed the mandarin fish they cultivate there, having given up on carp, which polluted the water.

and generally damage the seafloor. And the products coming out of Zhangzidao are very expensive. Sea cucumbers—small, bumpy, sluglike relatives of sea stars—sell for as much as \$250 apiece in China. As in the U.S. and Europe, Chinese sustainable seafood seems to be primarily for the wealthy.

### BRINGING CONSUMERS ALONG

STILL, THE UNPRECEDENTED SCALE of the project hints at a potential solution for China's massive seafood demand. The trick is to make sustainable seafood work for consumers at all income levels. “Marketing sustainable products is a big challenge in China, at least at this moment,” admits Yuming Feng, Zhangzidao's president. Consumers will have the final say, he says, adding, “Their question will be, ‘What’s in it for me?’”

For now Chinese consumers are not focused on the environment or willing to spend more to help save it, because they have a bigger concern in mind. “The Chinese government and the Chinese consumers are really looking for truthful products” related to food safety, says An Yan of the Marine Stewardship Council's Asia Pacific office.

Health scares over lead poisoning and melamine-laced milk have made Chinese consumers nervous about where their food comes from. But Yan argues that production changes aimed to improve food safety open the door to conservation. When Zhangzidao started its experiment, it exported most of its scallops to environmentally conscious buyers in the U.S., Australia and Europe. Today all its seafood stays in China, marketed as clean and healthy rather than environmentally friendly.

That pitch rings true in a market in nearby Dalian, where the desire for the product is obvious. I walk down aisles lined with sea cucumbers, crabs, scallops and conches, buffeted by calls in Chinese of “What do you want?!” Fresh clams squirt water onto my pants. Older women are scooping up prawns with dust-

pans under colorfully gaudy banners of grinning cartoon fish.

Almost every stall in the fish market claims its seafood comes from the Zhangzi ranch, which is unlikely because Zhangzidao mostly sells to big retailers and high-end restaurants. But it is telling that the Zhangzi brand is so coveted. “They have artificial reefs, and this is very healthy for the fish,” says Meng Ni Ou Yang, a stall owner who sells “island” products for an extra 20 percent. Another seller, 35-year-old Hong Zhe Liang, simply says, “The water is cleaner there.”

None of the fishmongers mention environmental concerns, and when asked, they say wildlife conservation is not that important to their customers. Yet other regions are experimenting with IMTA, too. Along the shores near Dalian and farther to the south in Sanggou Bay are endless expanses of kelp farms that incorporate elements of the technique on equally sprawling scales, though with decidedly less variety of life. To meet the massive demands of a hungry China, ocean aquaculturists will have to expand such models much further.

### CLEANER LAKES AND PONDS

CHINA'S HUNDREDS OF THOUSANDS of seafaring boats may dominate the global market, but all that seafood does not dominate the country's own consumption. More than 70 percent of the fish China eats comes from its lakes and rivers. Recent scares over freshwater pollution have made some diners nervous about traditional fish, however. Thus, any attempt to curb China's impact on the sea will require restoring faith in freshwater fish farms. A network of scientists up and down China's most significant fish-growing region is trying to do just that.

The importance of aquaculture around the Yangtze River is obvious as soon as one lands in Wuhan, 500 kilometers upriver from Shanghai. It is the center of the largest fish-growing region of the world's biggest fish-growing country. Surrounding the airport, under freeway overpasses and along the roads as far as the eye can see, every square centimeter of unused land is dug out, filled with water and growing fish.

“Look off to the left,” says Shouqi Xie, a researcher at the Chinese Academy of Sciences, as we pass seemingly unending lines of ponds. “This is why we call Hubei Province the land of 1,000 lakes.”

About 18,400 square kilometers of China—roughly the area of New Jersey—are fishponds. Although it may be hard for Americans to imagine, Chinese experts say one fifth of the world's animal protein comes from freshwater fish, half of which come from here, in China's heartland along the Yangtze.

But these days headlines about rampant water pollution and contaminated foods have eroded consumer confidence in traditional pond fare such as carp and catfish. “This is ridiculous,” Xie says. “We track fish through their entire lives. With wild fish, no one is tracking where they go or what pollutants they encounter.”

Even so, traditional freshwater farms are not exactly sustainable. Chinese aquaculture traces back to Fan Li, who was a fifth-century B.C. philosopher, tactician and adviser to the powerful king Goujian of Yue. After a successful military career, Fan Li retired to the lakeside town of Wuxi, where he wrote the world's first aquaculture manual. The 400-character-long pamphlet includes such details as the number of carp to start with, the best growing season and a recommendation to raise turtles to ward off the “flood dragon.”

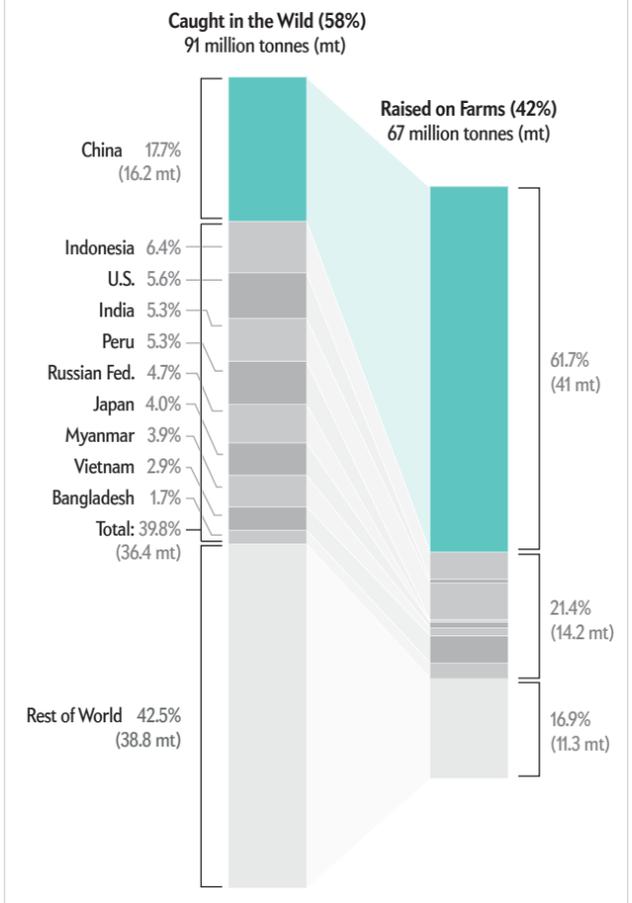
The ancient practices worked for thousands of years, with small ponds operating alongside terrestrial farms that maintained clean water and healthy fish. In the 1980s, however, the industry turned toward sprawling, industrial ponds. That shift, along with huge growth in other industries, caused heavy pollution. In 2007 the situation culminated in a fateful algal bloom in Tai Hu (*Hu* means “lake”), the legendary home of Fan Li. “Because most of the tap water in Wuxi comes from Tai Hu, citizens couldn't drink from their tap. The water ran black,” Xie says. “If you took a shower with the water, it smelled really bad.”

## LEADER BOARD

# The Biggest Fishmonger

China is by far the world's largest supplier of fish, crustaceans and mollusks—“seafood” from oceans, lakes and rivers. In 2012 (the latest data), China produced 177 percent of the seafood caught in the wild (left column, below), nearly three times as much as the next nation. Even more impressive, China raised 61.7 percent of the fish from saltwater and freshwater farms (right column). If wild fisheries, now disappearing, are to survive, countries will have to farm more fish, with China leading the way.

### Seafood Production, Saltwater and Freshwater (2012)



SOURCE: FAO YEARBOOK OF FISHERY AND AQUACULTURE STATISTICS, 2012, FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2014



**HUSBAND-AND-WIFE** team fertilize a pond they manage near Wuhan. Scientists are trying to help thousands of families operate their ponds more sustainably, vital to supplying China's ever growing demand for fish.

The 2007 black tide was a wake-up call for China. People could no longer trust the water they drank or the fish they ate. And although the bloom was not primarily caused by fish farms, the event has helped push Chinese aquaculturists to focus on high productivity that preserves the environment. People such as Xie are working on keeping water clean while increasing yield.

#### BALANCING ACT

ALL FRESHWATER ECOSYSTEMS are in a constant balancing act between too many nutrients and too few. The Great Lakes, for example, have invasive species that sap the water of nutrition, leaving it clear and oxygen-rich but dead. In contrast, the Yangtze has too many nutrients, such as nitrogen and phosphorus, and too little oxygen. The result is murky green water inhabited by the only creatures that can thrive in an oxygen-poor aquatic environment: algae.

For centuries the nutrients coming into and out of many fish farms were in a natural balance. But in recent years that alignment has shifted. Part of the problem is pollution, but another part comes from aquaculture itself. The most popular type of fish in China is carp—a fast-growing family that happily feeds on anything from algae to sewage. Carp excrete nitrogen-rich waste that settles into the soil. That nutrient, along with fish fertilizers, feeds the algae that then block light from plants that could produce oxygen. The cycle continues until very little can live in a lake except carp and algae. During a decade of rapid development, algae increased almost 20-fold in one Hubei Province lake and the lake's visibility dropped by half.

I contemplate this as I step onto a small speedboat on the shores of Liangzi Lake. The lake is eerily silent, and I cannot tell if the blanket above us is low cloud cover or smog. The water is greenish and perfectly still, like a giant expanse of weak pea soup.

Ten years ago dozens of pens, each full of carp, would have been stacked along the lakeshore, their waste killing everything else in the water. The local government asked Wuhan University to help restructure the farming in the lake, the second largest in the province. Jiashou Liu, Xie's colleague at the Chinese Acade-

my of Sciences, realized that the concentration of waste was feeding the algal blooms.

Today all the cages are gone. Fish farmers now manage the entire lake as one sort of cage, letting nature guide the fish. Also gone are most of the carp. Farmers and scientists focus on higher-value fish, such as crabs and mandarin fish, which pollute less but also decrease the number of fish in the lake. And they have added plants to the shoreline that put oxygen back into the water.

Once a year the farmers corral the fish into a corner of the lake and harvest them all together. As in Dalian, there is no need for fertilizers or expensive feed, which increase the nutrient load. And with more room to roam, the fish do not get sick as much. Amazingly, the lower volume does not affect the bottom line.

"The profit is better than what you would get from ponds," says Fu Jun Deng, a manager at one of the two companies that manage the lake. "It's very easy work. Normally all we do is patrol the lake and make sure nobody steals our fish."

Fewer fish, however, will not satisfy rising demand. And the lake is not pristine; it is murky, and a lot of algae still persist. But the water quality has improved. Oxygen is up, nitrogen is down, aquatic plants are flourishing along the shores, and the visibility is slowly getting better.

Similar projects are rehabilitating other large, natural lakes in the area, but they are still dwarfed by the many thousands of smaller ponds—each maybe the size of a football field—blanketing the countryside around them. These family ponds are truly feeding the nation, producing a great deal of food per hectare. Keeping the water clean and the fish healthy in these local operations is a challenge. Thus, in addition to bigger projects, scientists are innovating low-tech ways to raise a healthier, more sustainable product.

Congxin Xie (unrelated to Shouqi Xie), a professor at Huazhong Agricultural University, has been experimenting with so-called floating islands to purify water. Early one morning he drives me to a test pond near the small town of Gong'an. Sprinkled on the water are half a dozen white, plastic frames overflowing with water spinach. The frames look a little like giant,

floating window boxes. Xie has spent years studying how aquatic plants interact with their environment and eventually settled on this species because it grows fast and creates large root networks using massive amounts of nutrients. Xie says that with just a few floating planters in the past three months, the ammonia levels in the water have dropped by one third. (Too much ammonia kills fish.)

"The water quality has gotten better. Clearer," says Yung Chang Xu, one of the fish farmers who operate the ponds. There are "not as many dead fish as last year."

Chang's son takes us out in a wood boat to the pens, and Xie pulls off a few handfuls of spinach. The plastic frames, maybe the size of two or three bathtubs end to end, are not moored to the bottom but float around. The pens cost about \$150 to build but pay for themselves in a year if a farmer can sell the spinach as organic produce. At a nearby restaurant, a chef steams the spinach leaves in some kind of salty dressing, adds nuts and serves them alongside several species of freshwater fish. I am still not used to the flavor of carp (or their tiny bones), but the spinach is delicious and is quickly gone.

This mix of products is key, Xie says. Reforms have to benefit both the environment and the farmer, and scientists have to work closely with the locals. The spinach boxes here have satisfied both criteria, and local farmers say they plan to cover at least 5 percent of the ponds with them. Workers along the shorelines are busily building more.

Aquatic plants and animals have become a centerpiece for China's efforts to clean its waters. After the 2007 Wuxi algal bloom, scientists ramped up efforts to incorporate wetlands into fish farming. The Chinese Academy of Sciences began funding multiple projects along the Yangtze using freshwater snails, lotus, and dozens of other plants and animals to battle water pollution.

Ge Hu, a lake just upstream from Tai Hu, for example, no longer hosts fish pens. It is now covered in 2.6 square kilometers of water hyacinths cultivated to fight pollution. Nearby, Wu Jing Aquaculture Farm—a sprawling complex of industrial ponds—dedicates 30 percent of its ponds to a similar form of wetland filtration.

Another series of ponds attached to Luhu Lake in Wuhan once raised heavily polluting carp on its cooperative farm. With an intense 12,000 kilograms of fish harvested annually, farmers could make thousands of dollars per hectare if everything went well. But everything rarely went well. At that density, disease and pollution were rampant. In 2008, with the help of the Chinese Academy of Sciences, the farm added wetlands to the outflow area connected to the main part of the lake. Meanwhile the farmers switched from tightly packed carp to the mandarin fish, which is 10 times less concentrated, more environmentally friendly and commands a higher price.

"It's an experiment every year. We'll [introduce] 50 or 100 of one species [of freshwater fish] and then 100 of another type of species," says Hui Shang Xia, a 50-year-old fish farmer who has worked here for decades. "I've never lost money on a pond, but sometimes I make less."

Other solutions require more creative tinkering. For instance, scientists at the Chinese Academy of Fishery Sciences' Fishery Machinery and Instrument Research Institute in Shanghai have developed a machine to fix a problem common in smaller fishponds. The issue is poor photosynthesis in plants that could fil-

ter the nutrients. A lack of phosphorus in the water when the sun is shining limits photosynthesis, yet there is ample phosphorus in sediment at the bottom, says Hao Xu, director of the institute, as he points out across a massive complex of pea-green test ponds. Engineers at the institution have developed a machine powered by solar panels that stirs up the mud along the pond floor. When the sun is bright, it kicks up phosphorus for the plants. When the clouds cover the sun, the machine stops.

#### A NEED TO SUCCEED

CHINA'S RECENT EXPLOSION of wealth has fueled an appetite for meat protein that might be unprecedented in world history. Conservation efforts in both freshwater and saltwater must, likewise, be massive. The Chinese Academy of Sciences is working with about 30,000 hectares of ponds up and down the Yangtze River Basin. Zhangzidao is the largest ocean farm of its kind in the world, and it and the nearby kelp farm dwarf any other IMTA projects on the planet.

The work borrows many ideas from the U.S. and Europe, but one would be foolish to expect the aquaculture here to look like its Western counterparts. The U.S. and Europe favor cold-water fish such as trout and salmon that require highly oxygenated water. China prefers low-oxygen carp and catfish. Chinese ideas about ecosystem health are also very different. "What we would consider a polluted lake, in the Chinese thinking, is considered efficient food production," says Trond Storebakken, a fisheries expert at Norwegian University of Life Sciences near Oslo. "But an overpolluted lake is a disaster. Managing to keep this good balance—that's what impresses me."

Storebakken has consulted widely with the Chinese Academy of Fishery Sciences. He has traveled around China and has been stunned at how scientists seamlessly replicate natural systems—making use of the roles of predators, herbivores and filter feeders together. He has faith that China, after thousands of years of evolving and shaping its relationship with seafood, is beginning yet another chapter. "It's a completely different thing than what we are doing" in the West, Storebakken says. "They are mastering these challenges. Not to perfection—no way—but much better than anywhere else." ■

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#### MORE TO EXPLORE

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