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## Economy of Scales

Can fish farms nourish the world without despoiling the ocean? Stanford experts work to solve a feeding quandary.

by PAUL ROGERS

photography by JEREMY KORESKE



**Spend any time outside** in Canada's Clayoquot Sound during the winter, and you'll likely get drenched. Flanked by jagged misty mountain peaks that seem sprung from *Lord of the Rings*, Clayoquot Sound is a backdrop of rocky inlets and fjords, bald eagles and orca whales on British Columbia's west coast 250 miles

north of Seattle. The primeval spot averages 127 inches of rain a year—three times the downpour of its coffee-gulping, Space Needle'd metropolitan neighbor to the south.

So with the sun shining on a December morning, it's no surprise that Spencer Evans seems upbeat. Bounding out of a small boat that has just piloted through the Sound, Evans, 49, is the clean-cut general manager of Creative Salmon, a fish-farming company that operates six aquaculture sites in Clayoquot Sound. Joking with his employees, he climbs aboard the floating metal walkways of the company's Dawley Pass salmon farm, anchored near the shore five miles east of Tofino, the closest village.

"Hey, how am I doing in the hockey pool?" Evans asks the three crewmen he greets. Not good, they say, grinning. Below their feet, in the Sound's clear, chilly waters, thousands of silvery fish teem in nylon mesh pens. Altogether, there are 220,000 Pacific Chinook salmon here. They zip through the salt water in 30 floating cages up to 100 feet square and 50 feet deep. Their mission: to fatten up for an eventual trip to supermarkets and restaurants in the United States, Japan and Canada.

Twelve inches long now, the fish were placed in these ocean cages three months ago after a year in a hatchery. In another 15 months, they'll weigh 10 pounds each

and be ready for dinner plates. But for now, they are the ones doing the eating. Crew members feed them twice a day. Workers use underwater TV cameras to watch the fish, making sure to cut off food pellets at the right moment to avoid waste.

"As they get full, they drift downward," says farm manager Grant McCreath, peering into a flickering monitor. Fish glide past the camera, moving slowly, like a satisfied uncle pushing away from a Thanksgiving table. "There are 11,839 fish in there," he says of inventory in Pen 7. "They've just been fed. They're pretty happy."

Full, yes. Happy, perhaps. But oblivious to the gargantuan public policy issues they represent.

### **Creative Salmon**

generally wins high marks for environmental stewardship. But fish that the company produces—and millions more like them across Canada, Norway, Chile, China, the United States and other countries—are at the center of broadening debate as the global aquaculture industry booms. Is raising fish in captivity a way to feed the earth's growing human population and take pressure off struggling wild fish populations? Or is it doing more harm than good?

Among the top researchers tackling those questions is Rosamond Naylor, an associate professor of economics at Stanford and director of

Stanford's program on food security and the environment.

A perpetually upbeat economist whom everyone calls Roz, Naylor, PhD '89, has studied fish farming in Latin America, Asia, Europe and Canada—including a visit last year to Evans and his salmon pens near Tofino. Joining with other researchers, she has published influential studies on aquaculture in *Science*, *Nature* and other journals. Her work has explained, for instance, how rotting food, feces and dead fish from salmon farms can pollute waterways. It has broken new ground in



**HARD ROE TO HOE: Top, general manager Evans has been praised by Naylor for fish-farming practices that try to protect the environment. Bottom, The Dawley Pass farm is one of six sites run by Creative Salmon in the waters of Clayoquot Sound.**

measuring how farmed fish that escape can impact wild fish. It has looked at the effect of farmed salmon on rural economies; outlined how the environmental math doesn't add up when wild fish are fed to farmed salmon; and laid out how aquaculture might grow in sustainable ways. That issue is her main rallying cry lately. Reward the good guys. Gold stars and greenbacks for fish farmers who practice "green" behavior.

In January 2006, Naylor, the Julie Wrigley senior fellow at Stanford's center for environmental science and policy, received a \$110,000 grant from the David and Lucile Packard Foundation to work with the fishing industry and environmentalists to come up with a "green label" for farmed fish. It would give producers who use environmentally sound practices a way to charge more for their fish. She hopes the label could appear in stores by next year.

If more companies behaved like Creative Salmon, that would help, she says. The company eschews antibiotics and works to reduce the impact of waste on the environment. "They are not just going for maximum volume. They are going for maximum quality," Naylor says. But without a way to differentiate their product from fish at massive farms that don't tread as lightly, Creative Salmon won't be able to cover its higher costs.

"I think a lot of consumers are becoming more aware," Naylor says. "The rewards should go to the best operations, and in ways that are clear enough so that the bad guys follow."

**There's one thing** driving the world's current fish-farming boom: population. Now more than 6 billion, Earth's population is projected to increase to 9 billion by 2050, nearly all of it in developing countries. Think of adding two new Californias every year for the next half century. All those new people, many of them poor, will need food. Already, fish is the chief protein source for more than 1 billion people worldwide. During the past 50 years, the growth in human population has corresponded with a drop in many of the ocean's wild fisheries—blue fin tuna, cod, sea bass, rockfish—from decades of overfishing.

Enter aquaculture.

In 1970, only about 4 percent of the world's seafood came from fish farms. Today 31 percent does. By 2030, according to United Nations estimates, less than half of the fish humans consume will come from wild stocks. The fastest-growing animal food-producing sector in the world, fish farming is a \$54 billion industry. And as it has grown, aquaculture has become an "A-list" environmental topic.

There are four central concerns. Scientists say that large numbers of confined fish create breeding grounds for disease, such as sea lice, which can spread to wild fish. Another problem is escaped farmed fish. Some, particularly Atlantic salmon, have survived in the wild, then competed with wild fish for food or interbred with them to procreate new fish less able to survive in the open ocean.

The waste from fish farms can produce smothered "dead zones" in bays and inlets. In one of her published papers, Naylor noted that a salmon farm of 200,000 fish releases fecal matter roughly equivalent to the untreated sewage of 65,000 people. Many farms in Norway, Canada and Chile contain four to five times that number of fish.

But perhaps the thorniest problem is that some farmed fish eat too many other fish. It takes about three pounds of fish oil and fish meal from herring, anchovies and sardines caught in the ocean, for example, to produce one pound of farmed salmon.

They could eat grain instead, but then they wouldn't taste like salmon—and would contain fewer of the beneficial Omega-3 fatty oils that have spurred salmon's popularity.

"Intuitively, it makes sense: eat a farmed product, and it takes pressure off wild salmon," says Dom Repta, aquaculture campaigner for Friends of Clayoquot Sound, an environmental group in Tofino that urges consumers to boycott all farmed salmon. "But when you farm salmon—a carnivorous species—in open-net pens, there are concerns. It actually puts added stresses on the ocean."

**Roz Naylor**, 48, has been wondering how to feed the world without wrecking the oceans for nearly 15 years. During a volcano-climbing vacation in 1992 in Ecuador, Naylor heard about the destruction of mangrove swamps on the coast by fishermen who were raising shrimp. A few months later she returned to Ecuador—this time with three Stanford undergraduates from a class on world food issues in tow.

Aquaculture companies from the big city had come to rural villages, torn out mangrove trees and installed shrimp ponds. They made money. But in doing so, they destroyed the nurseries for young wild shrimp. When disease spread through the shrimp ponds and killed everything, the businessmen left. "Those were the critical habitats for wild shrimp," Naylor remembers. "I thought, 'Here is something so unsustainable. The bigger the production, the more the harm.' Sure enough, the whole industry there ended up crashing." The already-poor locals ended up with no farmed shrimp, no wild shrimp and no economy.

The crash matched issues that had driven Naylor's curiosity for many years—the link between economics and the environment. Her undergrads wrote honors theses about Ecuador. And Naylor got hooked on the problems of how to make fish industries safe for the world. "We're not going to be able to catch everything from the sea in the future," she says. "Let's move toward aquaculture efforts that are trying in earnest to create sustainable practices."

Not all fish farming is controversial. Environmentalists and marine scientists generally approve of the raising of oysters, clams and mussels. As filter feeders, these shellfish clean the water in which they are placed. Freshwater farmed fish—catfish in the United States, tilapia in China or trout in Europe—are considered safe for the environment because the fish are raised in inland tanks or channels so their waste and disease outbreaks will not spread if handled properly. Nor can they escape. Freshwater tilapia, in particular, can flourish on a diet of only grains, making it the "in" fish for environmentally conscious diners. The most common farmed fish is carp, grown in fresh water in China, the world's largest aquaculture producer.

**Increasingly**, however, the money fish in aquaculture is salmon. Produced in countries with protected coastlines and cold water—Chile, Norway, the United Kingdom and Canada—farmed salmon commands higher prices than most other farmed fish.

Twenty years ago salmon was a delicacy, available only part of the year and to the wealthy. Now, it is available year round, and at a cost many shoppers can afford. In many U.S. supermarkets, farmed salmon can go for as little as \$5 a pound, while wild salmon in season might run \$10.

"This is a relatively young industry. It uses public waters. There is no irreversible damage done to the environment by salmon farms," says Alex Trent, executive director of Salmon of the Americas, an aquaculture trade group. "If you take a salmon farm away, in six or seven months you'd never know it was there."

Health has become a high-profile issue with farmed salmon in recent years. A 2004 study published in the journal *Science* found that farmed salmon—particularly from Scotland and other European areas—contained more PCBs, dioxins and other possible cancer-causing contaminants than wild salmon. The contaminants build up in small fish, like herring, that swim in industrial areas and then are fed to the farmed salmon.

Specifically, the study found PCB levels that averaged 37 parts per billion for all farmed salmon studied, with wild salmon at 5 ppb. Yet all were dramatically below the U.S. Food and Drug Administration's fish consumption recommendation of 2,000 ppb for PCBs. The study's authors and environmental groups cited more stringent health standards of between 24 and 48 ppb that are set by the Environmental Protection Agency. However, people who eat one eight-ounce serving of fish at that level every month for 70 years increase their risk of getting cancer by only 1 in 100,000, according to EPA calculations.

Walter Willett, chair of the Harvard School of Public Health's nutrition department, told *Eating Well* magazine, "There is no evidence that these low levels of PCBs have any impact on human health." By contrast, he says, "we have strong evidence from human studies that fish consumption twice a week can reduce risk of sudden cardiac death by about one-third."

### **Dramatic success**

in the world of fish farming may breed new concerns. "Aquaculture is at a critical juncture," Naylor warns. "The technology for ocean farming has come far enough to expand into a whole range of new species—cod, tuna, halibut. It will be very lucrative, but potentially damaging to the environment."



Last summer, the Bush administration proposed a landmark plan to allow huge, floating fish-farm pens access to federal waters out to 200 miles. The idea, if approved by Congress as expected, would be to have the National Oceanic and Atmospheric Administration (NOAA) lease sections of the ocean



—and perhaps also abandoned oil platforms—to fish companies for 10 years at a time. The United States imports 80 percent of the seafood it consumes, creating a \$7 billion annual trade deficit, larger than any other natural resource except oil. The idea, NOAA officials say, is to expand the U. S. aquaculture industry fivefold, to \$5 billion, and recapture some of that business.



**EVERYBODY LOVES SALMON:** The money crop is raised in cages that are checked at least twice a week by divers. Nets are winched out and changed often because Creative Salmon doesn't use antifouling paint on them.

Some experts think the concept has real promise. In the first such high-seas aquaculture venture, University of New Hampshire researchers have raised thousands of cod, steelhead trout, halibut, haddock and other fish in 50-foot-tall, saucer-shaped underwater cages anchored six miles off the New Hampshire coast. In more than five years of operation, the university's researchers have found no increase in nutrient levels on the ocean bottom or adjacent waters: careful feeding practices and strong currents have kept the fish fecal matter under control, according to Richard Langan, a University of New Hampshire professor. No fish have escaped from the pens, which are made of the same super-strong composite fibers that NASA uses to keep astronauts from drifting away during space walks.

As Congress considers what rules to put on any open-ocean program, the Pew Charitable Trusts has formed an advisory task force to make recommendations. Among its members is former Stanford University law professor Byron Sher. A longtime California state legislator, Sher authored a bill in 2003 that banned genetically modified fish farming, and salmon farming in California ocean waters out to three miles.

"It is pretty clear that fish farming around the world is here to stay," Sher says. "I don't see any possibility that Congress will prohibit it in these offshore waters. If it is going to happen, we ought to be very careful about it and follow a precautionary approach."

**Back in Tofino,** Spencer Evans says he is doing nearly everything he can to make his salmon farms environmentally sustainable. He fallows two of the six farms for up to two years at a time to allow the bottom to recover. He uses no antibiotics. He has the support of the local Tla-O-Qui-Aht First Nations people, in whose traditional tribal waters the farms are located. To reduce the risk of disease, he puts about 25 percent fewer fish per cage than some other farms.

Those actions increase costs for Creative, a small company with only 46 employees. And although Whole Foods, America's largest natural foods company, sells Creative Salmon, other stores, like Wild Oats, won't. Adding insult, not a single restaurant in Tofino carries farmed salmon, even though salmon farms are a major local employer.

Evans has been frustrated in attempts to earn better acceptance and profits in the marketplace by labeling his salmon "organic." Neither the U.S. nor Canadian

governments allow fish to be labeled organic in supermarkets because nobody knows what the smaller fish they eat may have eaten. The U.S. Department of Agriculture has a task force studying the issue.

"We can't grow fish at the same low cost as the big companies," Evans says, "so we grow fish according to organic principles for consumers who are willing to pay more for that. It's our only way to survive."

To that end, there are scorecards to help shoppers choose the most environmentally sustainable fish; one of the best known is the Monterey Bay Aquarium's Seafood Watch Card. The card grades fish as green (good), yellow (okay), or red (avoid), based on the species' health stability, and how much harvesting practices harm the environment.

All farmed salmon is graded "red" at present. Aquarium officials acknowledge that some producers are doing a better job, but they say for now they have no way to tell them apart. George Leonard, a former Stanford postdoctoral scholar who is science manager of the Seafood Watch program, says he hopes by year-end to have a way to give a "yellow" grade to salmon farmed by conscientious producers.

"There are those people out there who say all farmed fish is bad," Leonard says. "But human population is growing, and we are eating more fish, not less fish. We are simply not going to get it from our wild capture fisheries. Farmed fish is the wave of the future. The question is what is it going to look like?"

Naylor agrees. To be the most environmentally sustainable, farmed salmon should have organic feed and no antibiotics, and be raised in low-density pens that are fallowed and rotated, she says. There should be regular water quality testing, no killing of marine mammals, and low percentages of fish meal used in the farmed fish food.

It's too late to mandate all those things in new laws, she thinks. Countries that have invested in fish farming won't want to enter political battles against a major job-creating industry in their rural areas. The best route is using green labels to offer economic incentives for good practices, she says, sounding every bit the economist.

"Often the environmentalists are looking for 100 percent perfection," Naylor says. "But that's not economically viable. We should be encouraging and motivating the companies that will get 90 percent there."

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PAUL ROGERS is the natural resources and environment writer for the *San Jose Mercury News*.

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