on cotton, an important crop plant in Texas. In 2000, a preliminary field trial of cotton transformed with APX showed that, under dryland agriculture, the altered plants produced 280 kilograms of cotton per hectare, whereas the wild-type yielded only 168 kg.

Back to the future

Other researchers have gone back to the basics: studying the physiological underpinnings of tolerance, work that could also provide new ways of boosting drought tolerance. For example, in studies of maize seedlings grown with limited water, plant biologist Robert Sharp of the University of Missouri, Columbia, found that roots adapt to the scarcity in several ways. The structure of their cells changes, permitting more longitudinal growth deep into soils. Also, the roots adjust osmotically, taking in more solutes and water. This response mechanism might be beefed up via changes in regulatory mechanisms, possibly further enhancing roots' vertical exploration of the soils, Sharp says.

Dorothea Bartels of the University of Bonn, Germany, and others are seeking clues from plants with an extraordinary ability to deal with drought, such as the resurrection plant (*Craterostigma plantagineum*), which can become completely dehydrated but revives with moisture. One of its secrets for success is a revamped chemistry that allows cellular metabolism to go into an inert, glasslike state. Curiously, although the plant tolerates desiccation, it doesn't thrive in saline soils, which suggests "a unique metabolism for the plant," says Bartels.

Washington University plant biologist Ralph Quatrano and his colleague David Cove of the University of Leeds, U.K., have just started studies of *Physcomitrella*, a moss that tolerates severe desiccation. Mosses were among the first land plants and may provide a good source of genes needed for coping with limited water. "Just 6 or 7 years ago, given the then capacity to control transformation, I would have scoffed at the [value of] 'weird and wonderful' genes from resurrection grasses or mosses," says Rockefeller Foundation scientist John O'Toole, who has developed research programs on drought tolerance for more than 25 years.

Now, he says, identification of such genes is a promising next step, offering researchers a significant new opportunity for manipulating drought tolerance into crops. More knowledge of plants' diverse physiological adaptations to drought, coupled with an understanding of their genetic basis, should help world agriculture do its part to conserve an increasingly rare resource, fresh water.

–ANNE SIMON MOFFAT

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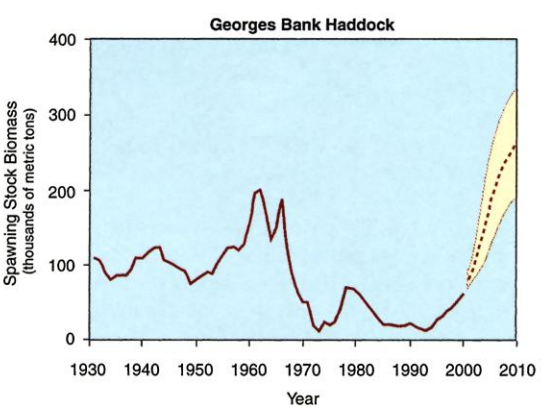
FISHERY SCIENCE

Bigger Populations Needed For Sustainable Harvests

The future of the New England fishing industry rests on the willingness of fishers, environmentalists, scientists, and the courts to find common ground

In 1998, scientists at the Northeast Fisheries Science Center (NEFSC) in Woods Hole, Massachusetts, took on a huge challenge. They helped calculate the mass of Atlantic scallops needed to support a stable and productive scallop industry, something that hadn't existed for decades. Their answer: It would take a fivefold increase over the recent depressed mass of scallops in the Georges Bank—a prime fishing area 100 kilometers off the Massachusetts coast—to bring back what had once been the continent's most productive scallop fishery. The calculation was more than an academic exercise. The New England Fishery Management Council (NEFMC) worked the target into its scallop management plan in 1998, which helped guide the opening and closing of the region's scallop grounds over the next 3 years. That injection of science into government regulation has paid off, yielding a robust harvest that seems to be sustainable, says Steven Murawski, director of the center's fisheries population dynamics branch.

Now scientists hope to replicate that success with similar calculations for the much larger groundfish industry, once the backbone of the New England economy. Groundfish harvests—which include 14 bottom-dwelling species such as flounder, cod, hake, and haddock—have been inching back since a crash in the mid-1990s prompted an economically wrenching series of fishing restrictions. Some populations are now nearing targets set in 1999, but new findings issued by NEFSC in March suggest that existing targets may be too low and that more reasonable goals would limit fishing to ensure the mass of some stocks climbs higher than levels seen at any time in the last 40 years.



Those findings could have a major impact on the livelihood of tens of thousands of people in the Northeast. The new biological targets have already been accepted—pending revisions and debate—as the goals for an NEFMC management plan that will guide regulators starting in August 2003. And they have influenced a court-ordered settlement between the National Marine Fisheries Service and conservation groups on new rules designed to help northeast groundfish recover. The settlement rules—approved last month by Judge Gladys Kessler, who tightened some provisions—slash the number of days commercial fishers can operate, mandate the use of coarser nets, increase the size of legally catchable fish, and add thousands of square kilometers to areas already closed year-round or during certain seasons. They went into effect 1 May.

Out of bounds? Scientists say the mass of fish needed to rebuild troubled New England haddock fisheries exceeds the estimated stock that has existed at any time since 1930.

The compromise rules seem to please nobody. Although everybody agrees that the fish are coming back, opinions diverge over how high the bar should be set, and how to tell if it's been cleared. Indeed, three of the four con-

CREDITS: (LEFT TO RIGHT) SOURCE: RUSSELL BROWN/NORTHEAST FISHERIES SCIENCE CENTER; VINCE STREANO/CORBIS

servation groups that took part in the negotiations declined to sign the settlement, complaining that the rules didn't go far enough. And most representatives of the fishing industry backed out too, arguing that the rules are far too restrictive.

NEFSC's estimates of the harvest rates needed to sustain a productive fishery lie at the heart of these disagreements. The center's experts marshaled a vast array of data to argue that the target biomass should be increased for more than half of the stocks. Those data include detailed catch statistics stretching back to the 1930s and 40 years of scientific surveys. For many species, the catch data includes the ages of the fish caught—critical information for estimating how many young fish reach maturity each year.

These so-called recruitment data are key to calculating the revised biomass targets. Older models don't use this information, and incorporating it raised the targets considerably—in some cases doubling the previous target biomass as the researchers reassessed the importance of strong recruitment. The result of this thorough comparison of many models and data, says Ransom Myers, a fisheries scientist at Dalhousie University in Halifax, Canada, better addresses the inherent uncertainty of projecting fish populations. Unlike previous targets, he says, the scientists have taken into account the shifting baseline problem—the idea that as time passes, fishers and researchers become used to populations that are slowly spiraling downward.

Jeff Hutchings, also at Dalhousie, calls the higher biomass targets "very brave, and very necessary." Striving for bigger biomass would prevent fish populations from sinking below a threshold that could trigger not only economic hardship but also fundamental changes in food webs that prevent the species from ever rebounding, he says. That's what happened with the Newfoundland cod population, still in dire straits despite a 10-year fishing moratorium.

But fishers are skeptical of the higher biologic targets and the corresponding bleak picture the report paints of stock status in the Northeast. "We're continually amazed by these reanalyses that push the numbers [for target population levels] up," says Jim Kendall, director of the New Bedford Seafood Coalition and a member of NEFMC, which drafts fishing management plans. He and others also wonder if the seas can support such large increases in every type of fish. Murawski says that's a fair question but that the researchers feel justified in pushing all populations back to at least 1960 levels.

Aside from their fundamental disagreement over population targets, both sides are at odds over the means to prevent overfishing. The new rules only limit fishing effort—how much time and energy is spent pulling fish out of the water—rather than regulating what is actually caught. Fisheries scientist Ellen Pikitch of the Wildlife Conservation Society says this means "you have to sit back and pray" that the fishers don't kill too many fish from species in trouble, preventing populations from rebuilding to the new biomass targets. Her group, one of the three that refused to join the settlement, criticized the rules for failing to impose a quota on each fish stock that would force fishing to stop once the catch limit is reached.

But the fishing industries object strongly to quotas. They argue that quotas fundamentally change the market structure for fish, fall more heavily on small-volume fishers, and can reduce safety by encouraging fishers to fish in bad weather in order to beat other boats to the fish, says Anthony Chatwin, a fisheries scientist at the Conservation Law Foundation in Boston—the only conservation group that signed the settlement. They're also hard to enforce in real time, he says. "They've just finished tallying the fishing mortalities for 2001," he notes.

A quota system appears to be the most straightforward way to implement the science, admits Chatwin, "but we need something that works on the water as well as on paper." Those who agreed to the settlement must now work on a longer term plan that will fully incorporate the new science, he says, and lay the groundwork for the greater harvests to come. **–KATIE GREENE**

CORPORATE RESEARCH

Japan Asks Why More Yen Don't Yield More Products

Officials look beyond a sluggish economy to understand why R&D spending hasn't translated into greater success in the marketplace

TOKYO—The importance of research is an article of faith within Japanese industry and government. "It is simply held to be true that investment in research and development is the biggest factor in keeping a company growing," says Tatsuro Ichihara, vice president for research at Omron Corp. "New technologies are very important for the nation's economic growth," adds Tagui Ichikawa, a science and technology policy official at the Ministry of Economy, Trade, and Industry (METI, formerly the Ministry of International Trade and Industry).

Customers first. Hitachi's Michiharu Nakamura says a healthy corporate research budget hinges on rising sales.

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But recent news is straining that belief in the power of R&D. Government officials are puzzling over an equation that shows a simultaneous rise in research spending and a decline in global competitiveness. The total has been buoyed by steady increases in governmental research budgets that offset a tightening of corporate spending on research. In March, the government released figures showing that Japan's R&D investment in 2000 was a world-leading 3.18% of gross domestic product, far ahead of the 2.66% ratio in the United States. Unfortunately, the news barely preceded an announcement that the nation has slipped into its second recession in 5 years, and that many of the biggest corporate R&D spenders—including NEC Corp., Hitachi Ltd., and Toshiba Corp.—were among a near-record number of Japanese companies announcing losses for the fiscal year ending 31 March.

Research managers say fixing the mismatch between spending and results will require help from both the public and private sectors. "The problem is that the fruits of the R&D are not going into commercialization," says Ichikawa. Takemitsu Kunio, general manager of research planning for NEC Corp., admits that their research efforts haven't helped the company as much as they should. "Our research has often been out of touch with corporate goals," he says.

Concerns about Japan's ability to commercialize high technology mark a dramatic turnaround from a decade ago, when Japan's high-tech companies seemed in-