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# WHEN CLIMATE CHANGE AND FISH COLLIDE

BY TOM ZELLER, JR.

**With a limberness that defies his 69 years,** Frank Mirarchi heaves himself over the edge of a concrete wharf and steps out onto a slack, downward sloping dock line bouncing 20 feet above the lapping waters near Scituate, Mass. He shimmies laterally along the pylons, steadying himself with a grip on some steel rigging, until he reaches the roof of the pilot house on his boat, a groundfish trawler called the Barbara L. Peters, after his mother-in-law.

He descends to the motor room and rubs a hand along a clean stretch of engine piping. "I'll be done painting in here soon," says Mirarchi, who has been harvesting cod, flounder and other quarry from the Gulf of Maine and, further out, from the lucrative shallows of Georges Bank for the better part of five decades. "Then I'll move outside."

Painting is about all the action Mirarchi's boat has seen lately. Facing massive cuts in government-proscribed limits to the groundfish species at the very heart of New England's commercial fishing economy, the Barbara L. Peters — like the 30 or so other nominally active boats remaining in this New England sector, and dozens more boats up and down the Northeast coast — has been locked hard against its pier, rising and falling with the tides but going nowhere.

"We're gonna lose a bunch of boats," Mirarchi says, referring to the high odds that some fishermen, perhaps even himself, will be forced to abandon the livelihood that has sustained them for decades. Mirarchi barely broke even last

PREVIOUS PAGE: DOUG ALLAN/ GETTY IMAGES

"It's a beautiful boat," says Frank Mirarchi, referring to his groundfish trawler. "It just doesn't have any fish to catch."

TOM ZELLER, JR.

year, and with official catch allocations for some crucial species down by nearly 80 percent for the season that opened May 1, he expects that he will be forced to put the Barbara L. Peters — only eight years old — up for sale. "What else am I going to do? My entire life's résumé is running boats, and they aren't hiring these days.

"It's a beautiful boat," Mirarchi adds. "It just doesn't have any fish to catch."

Why that should be so is a matter of heated and sometimes rancorous debate. Nature being what it is, after all, good years and bad years on the high seas are par for the course. And while federal regulators have been on a long and difficult quest for balance, managing the nation's historically over-harvested commercial fishing grounds remains an exceedingly difficult task, not least because determining just how many fish are out there at any given time still requires a bit of groping in the darkness. As one marine expert famously quipped,

**"MY ENTIRE LIFE'S RÉSUMÉ IS RUNNING BOATS, AND THEY AREN'T HIRING THESE DAYS."**

counting fish is like counting trees, except "the trees are invisible and keep moving around."

But a growing number of scientists, as well as fishermen like Mirarchi, recognize that another factor — global warming — is sending the already delicate and opaque mechanics of marine ecosystems into a period of rapid flux. Some research suggests, for example, that as ocean temperatures rise, many fish species are being driven into deeper waters or toward the planet's poles. Those same shifting conditions, meanwhile, are inviting historically anomalous breeds into new ranges — with unpredictable results.

The precise degree to which these phenomena are contributing to Mirarchi's current plight is difficult to say, but ample evidence suggests that such changes are already affecting fisheries across the globe. Last month, researchers at the University of British Columbia published an analysis revealing that a large roster of fish species have been on the move in response to rising temperatures for at least the last four decades, and that in some marine ecosystems, particularly in the tropics, fish abundance was quickly dwindling.

These and other impacts are expected to continue cascading throughout the aquatic food web, from tiny zooplankton to the higher-order and commercially valuable species on which fishermen like Mirarchi depend for their livelihoods. Indeed, despite decades of efforts aimed at restoring the health of the nation's commercial fisheries — which generate more than $116 billion in annual sales and employ more than 1 million people — rising temperatures, increasing acidity and other ocean changes are undermining years of acquired knowledge about how our oceans work and how their harvests can be sustainably managed.

This now has armies of scientists, conservation groups and regulators scrambling to get a handle on what's happening. In a new report released last month ahead of a national conference on fisheries management in Washington, D.C., researchers described climate change as "the single greatest challenge facing fishery managers."

And yet, critics say, efforts to monitor and account for the impacts of new climate variables on the marine food web remain too new, too few and woefully underfunded. This is particularly true given that it takes years to translate sound marine science into effective public policy, which in turn can determine

the success or failure of local economies along the nation's coasts.

"I'm going nuts," Mirarchi says. "I'm going all around to different meetings and talking to everybody, from regulators to congressmen to other fishermen to fishery associations, and everybody says, 'We don't know how to fix this.' None of us, individually — nobody knows how to fix this."

At the end of April, despite weeks of protests by fisherman and local politicians, federal regulators announced that they would try to fix it, at least in part, by maintaining steep cuts in catch limits for the 2013-2015 fishing seasons. Limits on cod, among the most historic and lucrative species associated with these waters, were set 78 percent below 2012 levels for the Gulf of Maine and 61 percent below last year's mark for Georges Bank. Varieties of yellowtail and witch flounder, haddock and American plaice have also seen dramatically lower catch limits.

Many fishermen argue that the fish are more plentiful than these cuts suggest, and that environmental groups and government scientists, who conspired to implement a new system for divvying up catch quotas among local fishermen in 2010, are simply inept and unable to provide an accurate measurement of fish abundance. But others suggest that the very real effects of climate change are now being made plain in New England's waters, as cod and other species seek out more comfortable conditions.

Mirarchi, who has acquired the sort of wry, world-weary temperament that often comes with a profession at the nexus of so many opposing interests, says there's lots of blame to go around. But until scientists and regulators get a grip on how the ocean is changing, he adds, one of the planet's most vital food sources — and the multibillion-dollar industry built around it — hangs in the balance.

As the new fishing season opened on May 1, researchers were reporting that atmospheric concentrations of carbon dioxide had topped 400 parts per million — higher than at any point in human history. Mirarchi, meanwhile, once again made the trek down to the Scituate town pier and boarded his boat — not to fish, but to paint.

"Something is different out there. You can call it climate change or whatever you want, but the whole thing is a mess," he says. "They project some fish as being abundant but we can't catch them. They project the others as being scarce and we can't get away from them. There's a real disconnect and we're not able to put the two halves together to make it work very well at all.

"And," he says, "it's getting worse."

### A BRUTAL EFFICIENCY

It may not be revelatory to note that fish


Fisherman Baldassare Noto unloads the daily catch from a commercial fishing vessel in Gloucester, Mass.

ANN HERMES/THE CHRISTIAN SCIENCE MONITOR VIA GETTY IMAGES

are a crucial source of nutrition to the human animal, though it's an easy fact to forget in economies of seeming abundance like ours. As it is, the Food and Agriculture Organization of the United Nations estimated in 2012 that, worldwide, the full complement of commercial angling, trawling and farming currently yields an annual haul of 150 million metric tons of fish, worth about $200 billion — of which roughly 130 million metric tons ends up feeding someone.

For a little fewer than half the planet's nearly 7 billion inhabitants, fish comprise as much as 20 percent of the animal protein in their diets — and a significantly higher percentage in poor and island regions where subsistence hinges on just a few basic and readily accessible staples like fish.

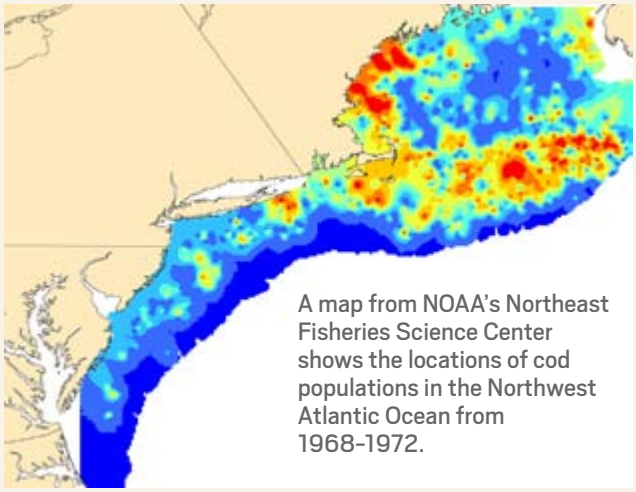
Inland fishing, to be sure, accounts for a chunk of the angling activity. But the lion's share of the global seafood bounty — about 80 percent — comes from comparatively small and patchy subsections of ocean habitat where fish thrive.

Meanwhile, mankind's proficiency at exploiting those spots has taken a heavy toll. Opinions on the precise numbers vary widely, but by most accounts a staggering number of fish stocks have been hunted to the point of wholesale population collapse. Of the 600 varieties currently monitored globally by the United Nations, for example, the organization estimates that roughly 90 percent are being either "fully exploited," meaning that any uptick in fishing would be unsustainable, or "overexploited," which is just what it sounds like: Humans are extracting fish at a pace that exceeds the stock's natural ability to replenish its numbers.

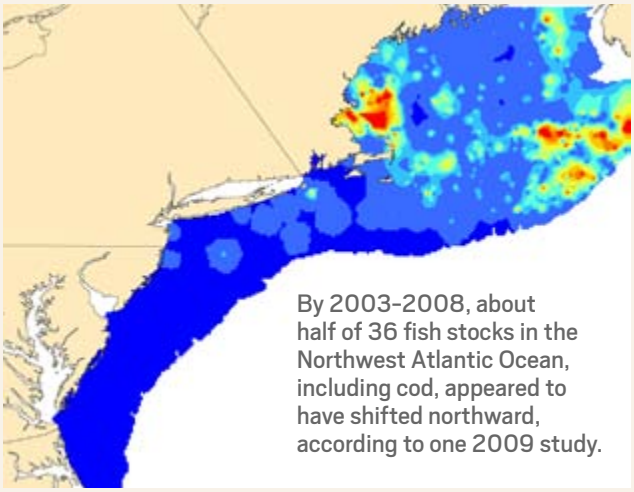
It's little wonder: Decades of technological improvements, including the rise of GPS and fish-finding sonar and the deployment of massive trawl nets and more muscular boats to pull them, have permitted commercial fishers to hunt with an ever more brutal efficiency — faster, deeper and over wider areas. And these developments have come in tandem with other ocean stressors like the increased demand for seafood, wanton coastal development and proliferating ocean pollution, all of which can spell trouble for anglers and their quarry.

Object lessons abound, including the collapse of Canada's Atlantic cod fishery 20 years ago. A combination of lax government oversight and the rise of rapacious trawling technologies had, by the mid-1990s, reduced cod stocks — the cornerstone of coastal economies in Newfoundland and Nova Scotia for the better part of four centuries — by more than 90 percent. Tens of thousands of fishing and related industry jobs evaporated amid an emergency government moratorium on cod fishing in the area. While two decades of restrictions have

## Cod on the Move



A map from NOAA's Northeast Fisheries Science Center shows the locations of cod populations in the Northwest Atlantic Ocean from 1968-1972.



By 2003-2008, about half of 36 fish stocks in the Northwest Atlantic Ocean, including cod, appeared to have shifted northward, according to one 2009 study.

JANET NYE, NEFSC/NOAA

begun to yield small signs of recovery, the amount of codfish in and around Newfoundland's Grand Banks remains just 10 percent of what it was in the 1960s, according to the intergovernmental Northwest Atlantic Fisheries Council.

Great Britain is now grappling with a cod collapse of its own, and the aggregate size of commercial hauls the world over — from Peruvian anchovies and bluefin tuna to Irish Sea sole — are shrinking as populations of fish go bust. A famous study published in the journal *Science* in 2006 predicted that, absent efforts to reverse the trend, all known commercial seafood species faced collapse by mid-century.

Whether these most dire assessments are overstated is a matter of debate, and some newer studies have suggested that a combination of government regulation is helping to stabilize things in some areas. But there is little question that, collectively, humankind has been making unsustainable use of a precious resource for a long time.

Signs of trouble for U.S. fisheries were plain as far back as the 1970s, when the waters around the Gulf of Maine and elsewhere had become an international free-for-all, with industrial-strength trawlers — including huge fleets from the Soviet Union — plumbing the depths just 12 miles off the American coasts with relish. One estimate has suggested that by the mid-1970s, annual harvests were removing as much as 60 percent of the adult cod from populations along the U.S. and Canadian coasts — three times the level considered sustainable for the long term.

In an effort to establish some order, the 1976 Magnuson-Stevens Act officially extended the territorial rights of the United States — and the economic benefits therein — out to 200 miles, and it laid down some basic tenets for sustainable fishing. The legislation was updated in 1996 and 2006, and Congress is now considering whether to reauthorize

the act again this year — all in an ongoing quest to establish the optimal suite of controls, which can range from limiting the number of days commercial anglers are permitted at sea, capping the amount of fish that can be caught, or closing certain areas to fishing altogether, depending on what experts believe any particular fish stock can handle.

In 2010, the New England Fisheries Management Council — one of eight such bodies that oversee commercial fishing in the U.S. under the auspices of the National Oceanic and Atmospheric Administration — refined the controls by implementing a "catch share" system for the region's highly prized groundfish. Modeled after similar systems used by various other U.S. and international fisheries, the idea is simple: Government scientists, using a combination of historical catch data and trawl surveys, determine the size of a fish population and how much of it can be sustainably caught. That total catch limit is then divvied up as "shares" among the region's commercial fishermen, who can then pursue their allocations on the high seas, or sell them to other anglers on an open market.

Catch-share systems are by no means universally popular, and the jury is still out on their overall impacts. Some recent studies suggest, for example, that while they may help to stabilize fish populations, they are less effective in restoring health to the marine ecosystem, which would ideally include boosting the overall biomass of the target fish that remain in our oceans.

This year's drastic cuts in cod allocations, which met with angry protests ahead of the season that opened early in May, suggested to many critics that the catch-share system in New England was an utter failure. But some environmental groups and fishery regulators insist that the system is both sound and necessary, explaining that an earlier sampling anomaly led them to overestimate certain stocks in the preceding years and forced them to make big cuts in the current season.

"We know that for some fishing communities that have relied heavily on cod, haddock and flounder, the next several years are going to be a struggle," said John Bullard, the northeast regional administrator for NOAA's fisheries division, at the end of April, in a public defense of the cutbacks. "We've done everything we can to include measures that may help soften the blow of quota cuts, but it's going to take a collective effort to find more ways to keep both the fishery and the businesses that support it viable while these stocks recover."

The more pressing question now, however, is whether any management strategy can bring the cod, or other traditional species, back. Optimists surely can point

to year-over-year improvements in the percentage of stocks that federal regulators consider to be overfished in the U.S. But scientists are also mindful that 150 years of carbon pollution have begun to break down and reassemble the undersea environment in ways we do not fully understand. Indeed, for all the concern over the impacts of global warming on land-based agriculture, forests and glaciers, the oceans are at the front lines of the climate assault, becoming increasingly acidic and absorbing as much as 80 percent of the additional heat being generated by the greenhouse effect.

Given that cod development and ecology is so dependent on water temperature, one analysis has predicted that if bottom temperatures in the Gulf of Maine rise just one degree Celsius in coming decades, yields of the fish could drop by 21 percent.

> **"THEY PROJECT SOME FISH AS BEING ABUNDANT BUT WE CAN'T CATCH THEM. THEY PROJECT THE OTHERS AS BEING SCARCE AND WE CAN'T GET AWAY FROM THEM."**

A one-degree uptick from that would reduce cod catch by as much as 43 percent, and higher temperatures would likely drive the fish out of the area completely.

At the end of April, NOAA's Northeast Fisheries Science Center reported that sea surface temperatures on the Northeast continental shelf — which runs roughly from Cape Hatteras, N.C., on up through the Gulf of Maine — had reached their highest level in 150 years of recording. The change, the agency noted, appeared to be impacting distributions over the whole stretch — from black sea bass, summer flounder and longfin squid to butterfish, American lobster and, of course, haddock and cod.

But scientists and regulators still don't have a good handle on how the full array of new climate-driven variables — rising temperatures, changing currents, shifting thermal layers, increasing acidity — are combining to alter the ecosystems in which our favorite seafood items live and breed. "It isn't always easy to understand the big picture when you are looking at one specific part of it at one specific point in time," said Michael Fogarty, who heads the Ecosystem Assessment Program at NFSC, in a statement accompanying the historic temperature data.

"What these latest findings mean for the Northeast Shelf ecosystem and its marine life is unknown," Fogarty said. "What is known is that the ecosystem is changing, and we need to continue monitoring and adapting to these changes."

Dr. Jeffrey Runge of the University of Maine deploys "bongo" nets in Maine's Damariscotta River Estuary in a hunt for *Calanus* specimens.

TOM ZELLER, JR.

## GROPING FOR ANSWERS

The chilly waters of the Damariscotta River Estuary mingle with Atlantic Ocean currents about midway up Maine's coast, roughly 60 miles north of Portland. About four miles from the estuary's mouth, aboard the research vessel Ira C., Jeffrey Runge, a marine scientist with the University of Maine and the independent Gulf of Maine Research Institute, grabs hold of a pair of shallow plastic drums, yoked side-by-side like giant bongos, as they are heaved out of the water by an overhead winch. Each drum is about two feet in circumference and open at one end. On the other, they are skirted with fine mesh nets that taper over several feet into a pair of narrow steel collection cylinders, each about the size of a loaf of bread.

Dragging the apparatus behind the boat for several minutes has drawn an aquarium of minuscule creatures into the cylinders, including a species of rice-sized zooplankton that can be seen darting and swimming, like so many sea monkeys, in the collection jars where they eventually end up. This breed of zooplankton is technically known as *Calanus finmarchicus*, Runge says as he raises a jar to his eyeball, and it carries a staggering payload of rich, fatty acids known as lipids. This makes it a crucial source of nutrition for, among myriad other creatures, foraging species like herring and mackerel — which, as it happens, are among the many food sources for predatory species further up the food chain, including Gulf of Maine

groundfish like cod.

The lifecycle of *Calanus finmarchicus* in the Gulf of Maine has been in flux in recent years, and Runge is among several marine scientists who believe that changes in the climate, including rising ocean temperatures, increased precipitation and drainage cycles along coastal estuaries like this one, are playing a role. If that's the case, the entire food web in this historically abundant fishery may be reorganizing itself in response to new environmental inputs, with implications across dozens of interdependent species, including humans.

"If this *Calanus finmarchicus* disappeared — no one has really done the quantitative analysis, though it's something I would like to try to work out," Runge says. "But what impact might that have on the system? How would that cascade? Just intuitively it seems like it would be a big effect. The warmer temperatures throughout the water coming from the Gulf of Maine — that really affects how quickly Calanus can metabolize their lipid supplies, and it's really dramatic."

Research like Runge's is both vital and woefully behind the climate curve. Speculation about the potential impacts on the oceans and marine life have been percolating in scientific circles for decades. But in terms of understanding and monitoring the changing dynamics of ocean systems as a whole, and what impact that might have on the fisheries that provide jobs, revenue and economic stability for dozens of coastal communities, we are, by most accounts, still groping in the darkness.

"I think fundamentally that this climate forcing is going to be big, and it's going to make for big changes in ways that we don't understand," Runge says. "I think we are fundamentally unprepared for that, in terms of infrastructure, and if we really had unlimited resources, I would like to see some kind of observation program in places like the Gulf of Maine, with much more extensive sampling and many more variables."

Efforts along these lines are underway, Runge notes, pointing to organizations like the Northeast Regional Association of Coastal and Ocean Observing Systems, or Neracoos as it is known, which is part of the wider U.S. Integrated Ocean Observing System. These entities, which grew out of the Integrated Coastal and Ocean Observation System Act of 2009, operate as federal-regional partnerships seeking, among other things, to improve and support marine commerce and science-based resource management.

In 2009, the National Science Foundation also authorized funding for the Oceans Observatories Initiative. The project aims to build a network of ocean sensors that measure the full complement of "physical, chemical, geological and biological variables in the ocean and

> WHEN SHELLED ORGANISMS ARE AT RISK, THE ENTIRE FOOD WEB MAY ALSO BE AT RISK."

seafloor" and provide "improved detection and forecasting of environmental changes and their effects on biodiversity, coastal ecosystems and climate."

In April, the Obama administration released a roadmap for implementing the president's own 2010 ocean policy plan, which is nominally aimed at improving the resilience of the nation's ocean economy. "Science is the foundation upon which sound management of ocean and coastal resources is based," John P. Holdren, director of the White House Office of Science and Technology Policy and co-chair of the National Ocean Council, said in a statement announcing the implementation plan. "The president's National Ocean Policy and the new implementation plan will help advance relevant science and its application to decision-making to strengthen the economies of our coastal regions while increasing their resilience and sustaining their resources."

But for all this brewing activity, such endeavors remain both embryonic and, given the scope of the problem and the austere economic posture of lawmakers, cash-starved.

Consider, for example, rising ocean acidification, a direct result of oceans absorbing excessive carbon dioxide pollution. As pH levels in marine waters drop, so too does the ability of so-called calcifying creatures — assorted corals, clams, oysters, sea urchins and some varieties of plankton — to develop. And as the Carbon Group at NOAA's own Pacific Marine Environmental Laboratory notes: "When shelled organisms are at risk, the entire food web may also be at risk." The sentiments echo those of the National Research Council, whose 2010 "national strategy" for addressing ocean acidification concluded that the ocean's chemistry is changing at a pace that "exceeds any known to have occurred for at least the past hundreds of thousands of years."

Coral reefs alone support a wide array of fish species and other ocean life, act as a buffer against shoreline storms and waves and floods, and are increasingly providing clues to new medicines for a variety of human ailments, from cancer and arthritis to heart disease. And yet, given the ever upward trajectory of atmospheric carbon dioxide concentrations, scientists in December suggested that virtually every coral reef might be dead or dying by the end of this century.

Given the dire outlook, many stakeholders argue that far too little is being done.

One study, prepared in 2012 by the National Marine Sanctuary Foundation, noted that federal funding for research

Coral reefs are a fundamental part of the ocean food web, and one study suggests their existence is in danger due to increases in acidification.

GEORGETTE DOUWMA/ GETTY IMAGES

and monitoring of ocean acidification averaged about $29 million annually over the last four years. The foundation compared this to estimates, both public and private, of how much cash will actually be needed to address the problem in coming decades. The Ocean Carbon and Biochemistry program, a joint effort supported by the National Science Foundation and NASA, suggested that as much as $100 million annually — more than three times current funding levels — would be needed over the coming decade.

Taking a wider view of ocean science and management, the bipartisan Joint Ocean Commission Initiative, in its ocean policy report card last year, put the issue bluntly: "Ocean management, science, and education programs remain severely underfunded, hindering them from effectively supporting our national security and economic interests and undermining the health of ocean resources."

### A 'PHENOMENAL WEIRDNESS'

Perhaps not surprisingly, these shortfalls have left fishermen, regulators and coastal economies flat-footed. Runge points by way of example to shifts in the growth process of one of Maine's iconic seafood staples: the lobster. Warmer waters caused the prized crustaceans to molt earlier than expected last year. "It contributed to a mini-economic crisis in the lobster industry here in Maine," Runge says. "You had this early molting, and then there was a supply of lobsters that now were of size much earlier than usual, and processors in Canada just weren't ready for that. So you had this tremendous oversupply of lobsters early in the year that flooded the market and the price just took a nose dive."

Early molting appears to be underway again this year — and similar behavior and lifecycle shifts are being documented in fisheries the world over. In September, scientists at the University of British Columbia reported that warming oceans appeared to be causing fish to get smaller. The study, published in the journal *Nature Climate Change*, modeled some 600 fish species from oceans all over the globe, projecting that in aggregate, average maximum body weight of fish was likely to decrease between 14 and 20 percent over the first half of this century.

Last spring, Britain's Marine Climate Change Impacts Partnership, which unites a wide array of scientists, government agencies and industries, issued an analysis that found "clear changes in the depth, distribution, migration and spawning behaviors of fish — many of which can be related to warming sea temperatures." Sole were reported to be moving away from the Netherlands and toward the eastern edges of the English Channel, the group noted, while sea bass and red mullet had drifted northward.

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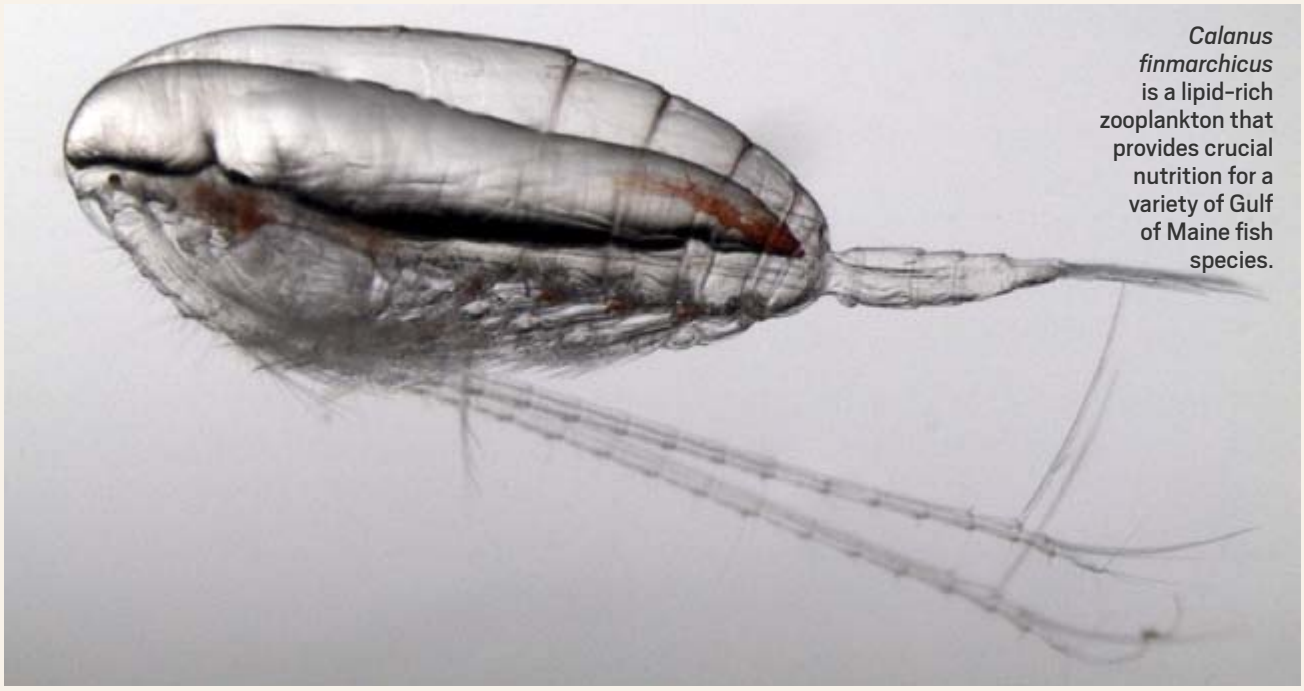


*Calanus finmarchicus* is a lipid-rich zooplankton that provides crucial nutrition for a variety of Gulf of Maine fish species.

CAMERON THOMPSON, UNIVERSITY OF MAINE/GULF OF MAINE RESEARCH INSTITUTE

Many of the Gulf of Maine's subarctic species — including Runge's *Calanus finmarchicus* — are already at the southern extent of their range, and experts suspect they are slowly being replaced by species migrating up from more temperate waters to the south. As the numbers of precious cod mysteriously dwindle in the gulf — possibly migrating north and westward with the *Calanus* — Mirachi and other fishermen are reporting increasing numbers of shortfin squid, black sea bass, blue crab and other species that had never been here in appreciable numbers before.

One common response to all this is, of course, so what? If changing ocean characteristics drive some fish away, others will likely arrive, suggesting that dry-docked fishermen like Mirarchi, and the fish-dependent economies of which they are a part, need only to adapt to new quarry. The U.K.'s MCCIP noted, for example, that rising populations of sea bass, red mullet, anchovy, octopus and squid, among other species, could represent new opportunities for British fishermen.

But Jake Kritzer, a senior scientist with the Environmental Defense Fund who also serves on the New England Fishery Management Council's science and statistical committee, suggests it's not that simple. "Just because we've seen some black sea bass in the Gulf of Maine doesn't mean we're going to have a viable black sea bass stock in the Gulf of Maine anytime soon, and therefore that we can write off cod and just shift our attention over there," Kritzer says. "And even if it does, in order for it to be sustainable, we still need to understand

the stock dynamics of black sea bass in the Gulf of Maine, which is something we've never had to look at before."

Add to that uncertainty the sizable time lag that exists between scientific understanding and its translation into public policy, and it's likely that the intersection of commercial fishing, environmental conservation and government oversight is going to become increasingly chaotic and contentious in coming years.

Writing in the journal *Nature* last month, the researchers from the University of British Columbia, whose new analysis suggests that fish and invertebrate movements in response to warming waters have been underway since the 1970's, suggested the stakes were high for everyone. "This study shows that ocean warming has already affected global fisheries in the past four decades," they wrote, "highlighting the immediate need to develop adaptation plans to minimize the effect of such warming on the economy and food security of coastal communities, particularly in tropical regions."

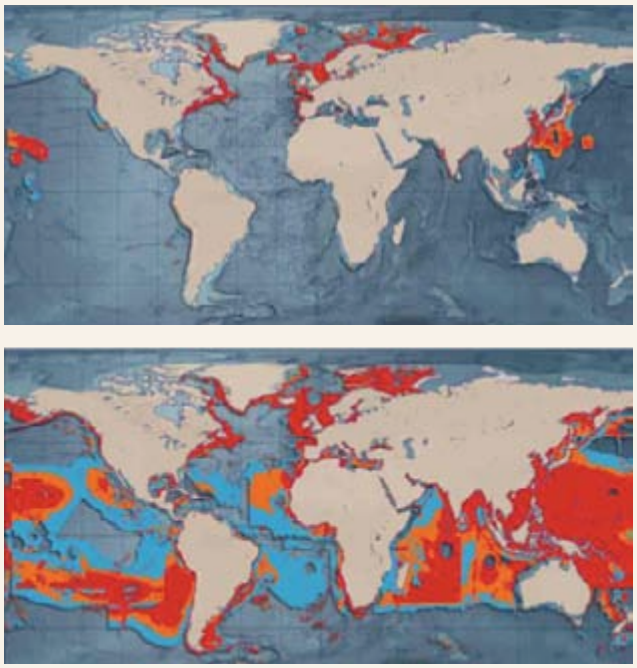
Of course, that's easier said than done.

"It's an immensely complicated situation," Kritzer says. "You have climate change overlaying everything, and it seems to be changing the way everything works, which means we have a lot of problems. It's getting harder and harder to assess the stocks, to model them and understand their dynamics and predict what's going to happen. Because those models are based on years and years of experience reading fish stocks and studying them, they have been tested over a long time and they rely on a certain set of assumptions and conditions that now seem to be rapidly changing. Tools that have been fairly well established and worked well in the past just don't seem to be working as well anymore."

Until science gets a handle on things, Runge says, that's going to be a social, economic and regulatory problem. "I think we're just going to be responding kind of blindly to what happens."

Down the hall from Runge's office at the Gulf of Maine Research Institute, Andrew Pershing, an ocean ecosystem modeler, has been enthusiastically documenting historically high ocean temperatures in the area and what he calls the "phenomenal weirdness" unfolding in the Gulf of Maine. "This event is larger than the Midwest drought, and like the drought, it has impacted ecosystems and people," he wrote last October. "However, because it took place in the ocean, it will be several years before we know the full extent of its impact."

In a meeting at his office, Pershing says that this is the task that he and his fellow ocean scientists now face. "I just really feel like there's a lot to be learned," Pershing says. "I think that we



## World Fishing Fleet Expansion

To measure fishing intensity, researchers used the fish landed in each country to calculate the "primary production rate," or PPR for each region of the ocean. PPR describes the total amount of food a fish needs to grow within a certain region. The red areas depict the most intensively and potentially overfished areas. Between 1950 (top map) and 2006 (bottom map), the area fished by global fishing fleets has increased ten-fold.

KEY

- At least 10% PPR extraction
- At least 20% PPR extraction
- At least 30% PPR extraction

ADAPTED FROM WWF'S 2012 LIVING PLANET REPORT.

can view it as doom and gloom, as a lot of challenges, but I think there's also — I feel like this region has the potential to be a really interesting example for the rest of the country, or the rest of the world, for demonstrating how you manage a fishery through climate change."

### IN THE MEANTIME

Last month, as eleventh-hour debate was brewing around the tough new catch limits for New England, several hundred fishermen and an assortment of local and national politicians from the Northeast gathered in Boston to air their grievances and entreat regulators at NOAA to increase the looming quotas.

"We're here to fight for a way of life that we believe in," Sen. Elizabeth Warren (D-Mass.) declared at the outset of the rally, "and that's what we're going to do, and we're going to do it together."

In the end, however, NOAA didn't budge.

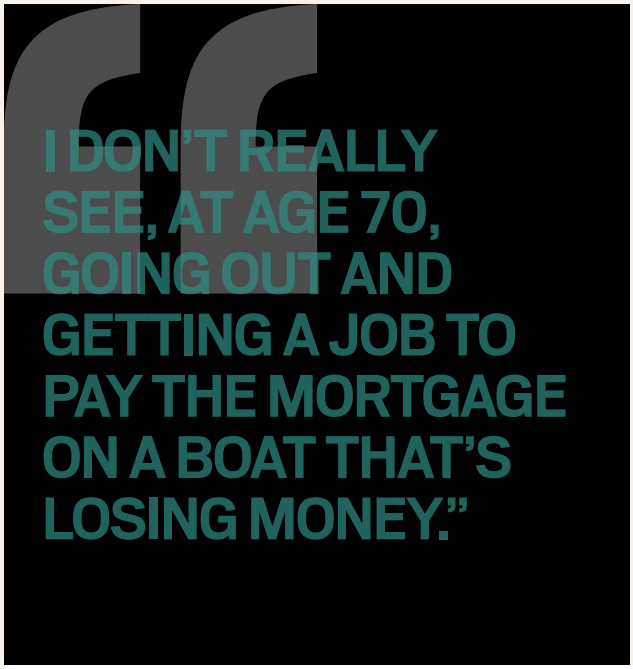
Mike Fogarty, the marine biologist and head of the agency's ecosystem assessment program for the region, defends the government's fish stock analyses — though he adds that more integrated approaches to understanding and modeling the ocean biosphere, including the ability to identify and fold in crucial new inputs arising from climate change, remain a work in progress.

He points to NOAA's nascent Integrated Ecosystem Assessment program, which is based on a wider regulatory philosophy called ecosystem-based management. The doctrine aims, for example, to move away from blunt, species-by-species counting and quota-setting in favor of continually taking the pulse of an ecosystem and all its various interdependencies as a whole. This includes not just a more thorough understanding of how a given natural resource lives and breathes, but also how

society derives economic benefits from it, and how humans function as fundamental parts of the machinery — both delivering impacts to, and absorbing consequences from, the environment.

Accurately accounting for all the new variables being introduced by ever-rising carbon dioxide emissions will, of course, be fundamental to this holistic management approach — though again, it's all just getting started. "The basic situation is that consideration of climate change issues is beginning to be taken into account [and] into management," Fogarty says. "But we have a long, long way to go."

That's cold comfort for Mirarchi. Inside the pilot house of his trawler, he grips a Styrofoam cup of coffee and ticks off the grim arithmetic that lies before him. This, he says, will likely be his last season as a fisherman. "Understand, I was already at zero last year with quotas for twice as much fish," he says. "So you do the math: If Frank is at zero with 2x fish, where is Frank with 1x fish? Somewhere below zero.




"I don't really see, at age 70, going out and getting a job to pay the mortgage on a boat that's losing money," he continues. "My wife really doesn't."

Last September, as it was becoming clear that the area's groundfish anglers would be facing steep cuts in catch allocations this season, the Commerce Department issued a disaster declaration for the entire fishery, giving some hope to Mirarchi and his fellow fisherman that they might be able to weather another bad year. Some funding for this was initially tucked into the aid package following Hurricane Sandy, but Republicans in Congress ultimately stripped it out. To date, lawmakers have been unable to agree on funding for beleaguered fishing communities in New England.

Asked if he was worried, Mirarchi chuckles briefly before growing more serious. "How would you feel?" he says. "You spend your whole life doing something, and all of a sudden everything you learned, everything you taught your kids, it's worth nothing — because it doesn't make economic sense anymore."

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