

# SEA OF CHANGE

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## ABSTRACT

The Gulf of Maine is warming at a faster rate than 99.9 percent of the world ocean, a trend with uncertain implications for the last great maritime fishery: American lobster. Every year, fishermen, scientists, and managers wait to see if the fishery reverses its fantastic growth, which has been a salutary effect of climate change over the past three decades.

The gulf has as many horizons as it has islands, and nobody knows the whole thing. Like the story of the blind men and the elephant, every person you ask, even the most expert, will describe a different gulf to you, and a different crisis. What's clear is that the ecosystems of the region have been shaped by many different pressures: domesticated by management, depleted by overfishing, shuffled by natural climatic cycles. The future of the gulf will depend not just on the trajectory of ocean warming, but on whether people can rethink the way we use the environment, and adapt to a changing world.

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Larry Moffet is selling his boat, a white 36-footer with aquamarine trim. He has captained it for two decades, the fifth boat of his lobstering career. He couldn't find a sternman to hire last season, a business proposition that's always been a sure thing in Stonington, Maine's lobstering capital. Bait prices have been wickedly high; 2019 was a dismal year for herring, and lobstermen have been obliged to load their traps with rockfish flown in frozen from British Columbia, and rosefish from as far away as Uruguay.<sup>1</sup> The profit margin for lobstering, fat just six or seven years ago, has been whittled razor thin. Moffet knows that if his 300-horsepower engine were to fail he couldn't afford to replace it.<sup>2</sup> "I can't quite wrap my head around it," he tells me, confronting his retirement. "In some ways, it's a relief."<sup>3</sup>

It's a greater relief to his daughter Lydia. It is dangerous for anyone to go out on the water alone, especially an old man of seventy. Lydia once employed me for a summer washing dishes in her bakery, but this is the first time I'm meeting her father. He's very tall, wearing house clogs and checkered flannel. His face is long and creased, framed by lank hair that's still dark. I've seen his oil paintings of light-filled seascapes hanging around town. We are sitting in the timber-frame house he and his wife built in the woods, brick red on the outside, clean and raw on the inside. It is not unusual for a lobsterman to have several trades; it's important to have insurance against the unpredictable. Around here, there are many ways for life to feed you. Mostly, though, it's been lobster.

Every season, Mainers wait to see if the lobster fishery finally reverses its wondrous growth, which has been a salutary effect of a warming ocean. Starting in the 1990s, American lobster, in a portentous migration, abandoned the fishing grounds of Massachusetts, Connecticut, and Rhode Island and began to settle in the Gulf of Maine. This move had devastating consequences for the lobster strongholds of southern New England, but was an economic boon for the fishermen in Maine who had recently watched their longtime livelihood, Atlantic cod, collapse and fail to recover. All along the coast, lobster has brought a heady influx of cash to small towns. Fishermen bought big, tricked out boats, and rumor had it that if a young man brought his lobstering permit to the bank, they'd loan him anything.<sup>4</sup> Lobster now accounts for three quarters of the value of Maine's marine resources. In 2016, that was \$1.67 billion at the dock.<sup>5</sup>

Robin Alden, who served as Maine's Commissioner of Marine Resources in the mid-nineties, says that people have been foretelling the doom of the lobster industry for decades. But in the last few years, tipping points have begun to loom in the Gulf of Maine.

"Because I've been thinking about complex systems for a long time, I'm just aware that we have no clue what's going to happen," she says. "And it's happening much faster than I ever thought."



In 2012, superstorm Sandy slammed New York City, bringing home, for millions of people, the visceral threat of climate change. Up the coast in Maine, the heat arrived in the form of a marine heatwave. "What happened that summer was really a shock," said Alden.

"Usually we have north winds start in September," Moffet remembers. "But in the winter of 2011, it never got cold." He knew that meant the lobsters would molt early, as early as May. Sure enough, "that was the year the famous glut came." For the first time in memory, Maine lobsters molted twice in a single season. Two classes grew to legal size for taking. Imagine a crop that bears fruit and ripens twice.

There were stranger things adrift that year, out in the pelagic zone. Sailors were startled by gray fins in the water, thinking they belonged to sharks, but the truth was weirder: giant mola mola, a blunt, trapezoidal fish from the tropics. Offshore lobstermen encountered them in groups as large as thirty. Beachcombers reported jellyfish washed up in unusual numbers. Longfin squid, clearly thinking they'd arrived to stay, laid their jelly pom-poms of eggs in the Damariscotta River.<sup>6</sup>

Scientists took notice. In October 2013, a meeting of the Regional Association for Research in the Gulf of Maine convened in the Holiday Inn in Portsmouth, New Hampshire.<sup>7</sup> Oceanographers, hydrologists, phycologists, ornithologists, and ichthyologists came armed with graphs, the sort frenetic with hot red lines. People who studied the gulf had been discussing climate change for years, but that meeting was the first time the field came together to trade notes with a sense of urgency. "It was basically like year 2100 conditions happening already," said Nick Record, who was there to share his data on the distribution of zooplankton in the gulf.<sup>8</sup> "It was one of the more interesting meetings I've ever been to."

That December, landings in the northern shrimp fishery were worrisomely low. The season was cut short, and the fishery was closed for monitoring.<sup>9</sup> A handful of fishermen were enlisted to monitor the shrimp for signs of recovery that could justify reopening the fishery. The following March, the Atlantic States Marine Fisheries Commission convened in Washington, D.C. to discuss the implications of climate change for the federal management of fisheries.<sup>10</sup> In March 2015, fisherman Arnie Gamage hauled a trap of shrimp onto the side of his boat.<sup>11</sup> It was spawning time, when northern shrimp migrate inshore. There wasn't much in the trap, but the females were heavy with gray eggs. "The fishery's gonna come back, I'm sure of that now," Gamage told News 8, pointing to the eggs, which would hatch into scads of hermaphroditic fry in the spring.

It didn't. The northern shrimp, an Arctic species which had been living at the southernmost extent of its range in the boreal gulf, became the first acknowledged casualty of climate change. In November, the Gulf of Maine Research Institute published a study in *Science* that included a remarkable statistic that foreclosed any hope of the fishery's recovery: between 2004 and 2013, sea surface temperatures in the gulf were warming at a rate faster than 99.9 percent of the world ocean.<sup>12</sup> By 2100, the gulf is projected to warm by 6.7 degrees Fahrenheit, a rate three times the global average.<sup>13</sup> The mainland will feel like Maryland.



Growing up on its coast, I always held a naïve conviction that the Gulf of Maine is a special place, unlike anywhere else in the world. The scientists who study the gulf know that it is, in fact, special in immutable ways. It is sometimes described as a sea within a sea, because although it is a corner of the north Atlantic, it has its own peculiar bathymetry that governs its circulation. It is a long depression in the continental shelf, from the lee of Cape Cod to the Bay of Fundy, which was scraped out by glaciers that only receded 10,000 years ago.<sup>14</sup> It is bounded by Georges Bank and Browns Bank, on the Scotian Shelf. These raised underwater plateaus, forested with kelp, were once broad islands where mammoths and mastodons roamed. They still serve as bulwarks against the Atlantic, a birdbath on the brink of a lake.

Warm water from the Gulf Stream enters through the Northeast Channel, which drives deep between the banks. Cold, salty water, derived from ice formation in the Arctic, enters the gulf on the Labrador Current, which skirts the coast of Greenland and washes over the Scotian

Shelf. The gulf is in the sway of its own physics, its long rectangular basin sloshing the incoming sea back and forth out of rhythm with the planet's tides. Twice a day, 110 billion tons of water are sent rushing into the Bay of Fundy and then sucked back out.<sup>15</sup> Nutrients are mixed and transported for miles. These waters are some of the most productive in the world.

When Pangea split, and the world's waters rushed in to fill the fissure, the new ocean was inoculated with species from the Pacific.<sup>16</sup> Not all species could make this migration. Marine mammals that are keystone species in the Pacific, like the sea otter and the killer whale, are absent from the north Atlantic. Instead the Atlantic is dominated by predatory fish. People have been fishing in the Gulf of Maine since the retreat of the Laurentide ice sheet at the end of the last ice age. A stone-age community of hunter gatherers, known as the Red Paint People, settled the shores of the gulf some 6,000 years ago.<sup>17</sup> Sustained by the bounty of the ocean, they never practiced agriculture. But they were a startlingly advanced society, with complex burial rituals and elegant slate bayonets. Arrowheads aren't the most interesting artifacts of this period—it's the shell middens, eroded along the coast by sea level rise, that hold the most valuable information about the gulf's ecological past. Those ancient landfills are filled with the jaw bones of codfish and the vertebra of swordfish.<sup>18</sup> For just about as long as there have been fish in the gulf, people have been fishing for them.

The gulf has as many horizons as it has islands, and nobody knows the whole thing. Like the story of the blind men and the elephant, every person you ask, even the most expert, will describe a different gulf to you, and a different crisis. "What do you call a lobster fishermen that's more than ten miles away from home?" Moffet asks. I've heard the joke before. "Lost."



Bob Steneck's lab at the Darling Marine Center, a compound of peeling white clapboard buildings on the water in Damariscotta, looks in the dead of winter like an abandoned summer camp. His tiny office is cluttered with the PVC pipes, tied into meter squares, that are his primary field equipment. He uses them to mark off survey plots on the ocean floor, and count lobsters. He's among the people trying to answer the billion-dollar question: what's going to happen to Maine's lobster fishery?

"You have to take with a big grain of salt some of the high-publicity papers," he says, echoing, more or less, how most people have prefaced their conversations with me about climate change in the gulf.<sup>19</sup> It's not just that scientists are trained to be skeptical of flashy statistics. The gulf is simply too complicated to be explained with a single figure, and the GMRI study, based on sea surface temperature recorded by satellite, only skimmed its surface. If you want to know what's happening to lobsters, you pay attention to the deep water.

Lobsters are ectotherms: unable to produce their own body heat, their blood is the same temperature as the sea. Their biology makes them exquisitely responsive to subtle changes in the water. "I am convinced that it's a fraction of a degree of change in the sea water temperature that completely changes the lobster's behavior," Moffet tells me. The threshold fishermen watch for is 13 degrees Celsius, when a lobster's metabolism kicks into gear, and the benthos comes to life: a bustling metropolis of lobsters eating, mating, and molting. In 2012, instead of waiting until the middle of August for the water to warm to 13 degrees, the sweet spot hit in the middle of June—giving lobsters time for a second molt before the season was over.

The bottom of the gulf is pitted with basins and canyons that hold deep, cold water—features that distinguish it from southern New England's shallow continental shelf, and interact

with the currents to delineate two zones of radically different character.<sup>20</sup> In Steneck's tiny office, a giant map of the Maine coast is fixed to the wall, with pins along it to mark lobster sampling dive sites. The two coastal zones are naturally divided by another wall that encloses a room with his desk in it. In the southwestern gulf, from Portsmouth to Penobscot, the water column is highly stratified; freshwater emptied from dozens of rivers settles in a layer above the cold and salty water, heating quickly because it never mixes down. In the northeast, cool backwash from the Bay of Fundy churns the sea from the bottom up, giving it a near-uniform temperature from the floor to the surface.

Steneck has been observing the gulf's benthos since the early 1980s. He used to take lobstermen down with him in a little submersible, to show them the underwater landscape they'd intuited from their traps and soundings but had never seen with their own eyes.<sup>21</sup>

He's more attentive to a different biological threshold: 12 degrees Celsius, the temperature at which lobster larvae settle.<sup>22</sup> Baby lobsters spend the first weeks of life drifting and eating in the surface waters. After their fourth molt, they are larger and more sensitive to light, and they begin to dive, looking for suitable habitat on the ocean floor. They search for cobbled terrain along the coast where there are lots of nooks and crannies for shelter, passing over muddy or sandy seabed. When they find it, they settle.

Every year, divers carry out the lobster settlement index, a survey of how many larvae have survived this vulnerable transition. This number is a good indicator for how large the lobster fishery will be five to ten years down the road, when those larvae have matured to legal size for harvesting. In 2017, the index sent the industry into a panic: the density of baby lobsters per PVC square meter was down by 17 percent.<sup>23</sup> The next couple of years didn't make up much ground, leading scientists and journalists alike to hand-wring over the impending decline of the fishery.

Steneck isn't so pessimistic. Based on an assessment of benthic temperatures, he thinks the baby lobsters have spread out over a wider range as suitable habitat has expanded on the seafloor, especially in the northeastern gulf, where the uniform temperature of the water makes it easy for the larvae to dive. If that's true, it bodes well for future year classes. But it does nothing to assuage Steneck's worries about the marine economy. "This is a dangerous place to be, for just a whole bunch of reasons," he says, "but especially as an ecosystem, when you are depending on a single species for about 80 percent of the total marine resource value."

Where ecosystems meet economics, sudden windfalls aren't always a good thing—and in 2012, it was a disaster. The heatwave flooded the market with 22 million extra pounds of lobster, causing the dockside price per pound to drop, in some regions, down to \$1.25, a seventy percent pay cut.<sup>24</sup> Those 22 million pounds weren't exactly extra, either—they represented a future harvest. The lobster fishery is replenished every year with a new class of juvenile lobster that reaches maturity at roughly the same time. For decades, the scrupulous industry had lived off the interest—lobsters that had just grown to legal size, with 3.25-inch carapaces—and left the rest in the bank.<sup>25</sup> In 2012, the fishermen ate into the principal. That's called overfishing.

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Fisheries can reel you in. Alden was a young journalist in Maine when she became deeply enmeshed in the fishing world, and then involved in its management. She served in the National Marine Fisheries Service in the late seventies, and then as Commissioner of Marine Resources.<sup>26</sup> She and her husband, Ted Ames, founded the Maine Center for Coastal Fisheries in Stonington

in order to give fishermen a voice in the research and management of their industry. “My mission in life has always been, how do we fish commercially and be able to do it forever?” she says. “If you could figure that out, human beings would have figured out something very, very important that has parallels in so many other arenas.”<sup>27</sup> But while economists, population ecologists, and even physicists have sought to impose order on them, fish continue to confound, exposing the limitations of our systems.

In 1995, Daniel Pauly, the biologist whose book Moffet was reading when I visited him, diagnosed fisheries science with what he called “shifting baseline syndrome.”<sup>28</sup> There is a fatal lack of historical data on the abundance of fish in the ocean, and this lacuna leads successive generations of researchers to misjudge the degree to which fisheries have declined over time. There are ways to build up that historical record, by taking oral histories of retired fishermen, and combing the historical record for less organized sorts of data that can attest to where certain species used to be abundant—for example, the shell middens.

But the value of population baselines rests on the assumption that ecosystems are undergirded by stable conditions in the environment. Climate change has kicked the bottom out of fisheries population models, and promises to alter the underlying conditions in ways that are rapid and unpredictable. Record, who makes oceanographic models for a living, says that scientists have had to shift their mindset “to think about the ecosystem in terms of surprises. We’re kind of going into this no-analog situation.”

To Alden, that uncertainty is a blessing in disguise. Climate change may be what’s needed to force a reckoning with the way the fisheries are managed. The Magnuson-Stevens Fishery Conservation and Management Act, drafted in the 1970s to provide a governance structure for its newly-claimed exclusive economic zone in the ocean, aims to conserve fish stocks from year to year so that they may be exploited at their maximum capacity. This is done through a system of permits and quotas that are undergirded by “the best available science” on marine population dynamics. According to Alden, “Federal management has continued to be a huge, complicated, bureaucratic, quasi scientific exercise, relatively unable to respond to changes.”

It’s a different story inshore, where the state manages fisheries within three miles of the coast. To harvest lobsters in Maine, you must have a license, and if you have a license, you must haul your own traps. The owner-operator structure of the fishery has been key to its long-term sustainability; generations of lobstermen, invested in the survival of the fishery, have practiced informal conservation methods like cutting notches in the tails of egg-bearing females and throwing them back.

“Three major Maine fisheries, lobster, scallop, and urchin, are now owner-operator,” she said. “And that means you can’t have fleet operations. If we hadn’t had that, we would have had industrial lobstering. It’s an amazingly profound thing to keep the scale small.”



At points in our conversation Moffet hoists himself out of his armchair, stumps across the room, and rummages for materials: a worn nautical chart; the wastewater application for the Bucksport aquaculture plant; *Vanishing Fish*, the collected essays of fisheries biologist Daniel Pauly. He unfolds the chart and spreads it on the rug.

Moffet’s lobstering permit extends southwest of Stonington to the waters off Isle au Haut. He traces his finger through a crumble of islands. This is where the cool Eastern Maine Coastal

Current peels off from its southerly route along the coast, and lets out into the belly of the gulf. He used to carry this map in his head, seeing, when he closed his eyes after a long day's work, where all his traps were sunk. These days, a fisherman is beholden to his GPS, some even to cameras and sonar that show the contours of the sea bottom as he passes above.

Warm water may invigorate the lobster, but it is not the only species to benefit from climate change. Moffet doesn't need to see the bottom to know that it has changed dramatically. Invasive tunicates slime themselves over his traps, glommed on so thick that a power hose can't pry them off. Some are sparkling and jewel-like, others are a fleshy neon ooze. The traps out behind the house are gummed up with leathery, ovoid sea squirts. Moffet believes they've taken over miles of pebbled sea bottom in his territory, crowding out adult lobsters and discouraging the settlement of juveniles. "It is *disgusting*, the amount and variety of stuff," he says, making a face. "That's another big factor in my deciding not to lobster anymore."

One of the most important changes in the benthos, according to Steneck, has been a winnowing of biodiversity. The Atlantic is already less biodiverse than the Pacific, but a long history of fishing pressure has brought about what he calls a "domesticated ecosystem." Lobster is not really a wild fishery by any stretch of the imagination, but a well-tended flock. In the summer, they mill from trap to trap like tourists wandering from bar to bar on a city block. They come for the bait, great football-sized wads of herring, alewife, or menhaden.

There are no lobster carapaces in the middens of the Red Paint People. Steneck nurtures a theory that the lobster population only exploded after it was relieved of its major predator, Atlantic cod. Cod is not, by nature, the modestly-sized fish found in today's supermarkets. It is a thuggish predator, huge and meaty, that swallows spiny urchins, shrimp, and clams (shells and all), and will tear a lobster limb from limb. For thousands of years, it dominated the kelp forests of the Gulf. But marine ecologists suspect that the kelp ecosystem hasn't been prevalent since before 1900, when cod began to be heavily fished by international fleets.

Ecologists use phrases like "boom and bust" and "flip and lock" to describe the volatile shifts that low-diversity systems undergo. Two decades ago, Steneck witnessed an ecological drama play out among a small cast of characters on the sea floor: urchins, algae, and green crabs.

Americans don't care for the taste of urchin gonads, bright orange and funky like the sea simmered down, and the spiny animal was a nuisance in lobster traps. So, when a lucrative Japanese market opened for green urchins in 1986, no regulations were put in place to limit their harvest. For a decade, Mainers dove and dredged.

In a more diverse ecosystem, the overharvest of one species might not signal a phase shift. "If you were to go to Southern California, you'd be talking about three species of sea urchins, five species of abalone, several herbivorous fish, several big snails that feed on seaweed," says Steneck. In the Gulf of Maine, the green urchin was the only effective herbivore left to keep the kelp forests in check. At its peak in 1995 the urchin fishery was worth over \$35 million.<sup>29</sup> Then there were no more urchins.

Sugar kelp and Irish moss retook the urchin barrens, bringing with them green crabs. Steneck waited to see if the urchins would return after the fishery was closed; he cultured and released urchin spawn, tiny Sputniks, over the forest, and periodically dove to see how many had survived. The crabs picked off every one. "Urchins are as rare as hens' teeth," says Steneck. "Last year we were diving all summer long. I think we saw three sea urchins on the entire coast of Maine."

But cold-water kelp forests are now vulnerable to the warming in the western gulf, and in their place a different sort of algae has taken hold.<sup>30</sup> Unlucky lobstermen haul up traps cloaked in

dark, matted weeds, like something sinister pulled from a drain. Scientists call it *Dasysiphonia japonica*, after its waters of origin in Japan. Fishermen call it gorilla hair.<sup>31</sup>

“Last year when I was doing lobster surveys, I was shocked at the shag carpet that I saw of this seaweed,” Steneck says. “It’s almost, in places, a foot thick.”

Biologically, *Dasysiphonia* is a perfect foil for the lobster boom: the temperature at which it thrives, 12 degrees Celsius, is the same threshold that enables baby lobsters to sound. As territory for lobsters has expanded, so has the habitat for gorilla hair. But what Steneck finds most worrisome about this invasive species is what happens after it dies. The algae rots just as quickly as it grows, creating pockets of anoxia on the ocean floor that suffocate marine life—gas bombs in the trenches.

Whether because of invasive species, or because the inshore waters are becoming too warm for the lobster’s comfort, an undeniable trend has emerged. The lobster fishery is slowly marching offshore, into the deeper, colder waters of the gulf—out of three-mile zone managed by the state, and into federal waters. This is a shift with huge implications for the industry, and especially for harvesters like Moffet who work in small boats close to shore, and don’t have federal permits.<sup>32</sup> But Steneck says this is the least of the lobstermen’s concerns.

“Most of what I’ve talked about is not on their radar screen. Right whales are on their radar screen.”



In theory, animals that can migrate for long distances to find food are more adaptive to climate change. The North Atlantic right whale eats copepods, the fat-rich zooplankton that also sustain juvenile cod, herring, and redfish in the gulf. For decades, whales made a regular circuit from the western gulf in the winter and spring, to the eastern gulf in summer and fall. Whale watch tours expected them in the Bay of Fundy; shipping lanes and fishing grounds were zoned around the whales’ expected route. Then, around 2008, the whales changed course, bypassing the Scotian Shelf and traveling all the way to the Gulf of St. Lawrence in Canada, and out to Martha’s Vineyard off Cape Cod.<sup>33</sup>

They entered a gauntlet of ships and fishing gear. Millions of lines, trailing from buoys on the surface down to lobster traps on the ocean floor, form a matrix that entangles errant whales, slicing blubber like wire through cheese. In the last three years, thirty right whales have died by entanglement or have been struck by ships. There are only some 400 whales left, and fewer than one in four are females of reproductive age. In 2018, the Center for Biological Diversity, Defenders of Wildlife, and the Humane Society filed a lawsuit against the US government for failing to protect the right whale according to the statutes of the Endangered Species Act.<sup>34</sup>

The changing behavior of the whales was a clue. “They’re the best observers we could have,” says Alden. “They seem to be very good at what they do.” The crisis prompted scientists to take a closer look at the deep water, where copepods hibernate for much of the year below 100 meters. What they found was even more alarming than the 2015 GMRI study had indicated: since 2004, the deep water of the gulf has warmed 0.5 degrees Celsius each year, twice as fast as the surface.<sup>35</sup>

The National Oceanic and Atmospheric Administration (NOAA) responded to the environmental lawsuit with a federal conservation plan that reduces the number of lines that Maine lobstermen can leave in the water.<sup>36</sup> Entanglement is not a new issue, and this is not the

first time the lobster industry has adapted its practices to create a safer ocean for whales. But the stressed industry—facing existential threats from all sides—has responded to further regulation like a cornered animal. Amid a renewed urgency to work together closely to understand how the gulf is changing, the whale issue is eroding trust between fishermen and the government.

The parking lot of the Samoset Resort in Rockport is jam-packed with big, new trucks. Rockport is a sleepy tourist town any other weekend of the year; even in the height of summer, it doesn't see more action than it does during the Maine Fishermen's Forum, a three-day symposium, gear show, and banquet and dance that attracts fishers and their families from up and down the coast. It's March 6, and this is the last large gathering any of them will attend for a long time.

Alden's lavender cardigan sticks out in the crowd of sweatshirts and denim. This forum is one of her legacies. She and Jim Wilson, an economist at the University of Maine, founded the Maine Fishermen's Forum in 1975, as a way to help fishermen advocate for their interests as a group, and to bring them together with scientists and managers to discuss issues in the industry.<sup>37</sup>

Both of us were tempted by the talk on fishermen's historical data collection happening at the Golf Club, but instead squeezed into the back of the Rockport Room to witness the inevitable showdown between the fishermen and the feds. One lobsterman likens the gap between NOAA and Maine fishermen to the one between Israel and the Palestinians.

"We want what's best too, you know, and we're trying."<sup>38</sup>



The most frightening aspect of climate change is its unpredictability. "It's not going to be a dead sea," Alden told me. "It's going to be something. It's just whether we know how to make our livings from it, and do it right. And we won't have anything to go on." The Gulf of Maine seems to have reached the frayed edge of precedent sooner than the rest of the world. So there is something uncanny in the fact that much of what we are seeing in the environment has happened before.

"Curious changes have been taking place," wrote Rachel Carson, "with many animals invading this cold temperate zone from the south and pushing up through Maine and even into Canada."<sup>39</sup> She was writing from her home in Boothbay Harbor, in the year 1955. The changes were certainly notable. A menhaden fishery, unheard of earlier in the century, was flourishing in Maine. Not only did yellowtail flounder and silver hake hazard around the arm of Cape Cod on warm currents, but their young grew to maturity in the balmy waters of the southern gulf. Whiting could be found in all seasons on Georges Bank; the odd sea horse, six-gill shark, and triggerfish made its way up from the tropics.<sup>40</sup> And lobster exploded in Maine: landings more than doubled from 7.6 million pounds in 1940 to 19.1 million just five years later.<sup>41</sup> "We hate to squawk about climatic changes," a reporter for fishing trade journal had written in 1949. "There may be something to it."<sup>42</sup>

In 1957, the Fish and Wildlife Service published a report titled "Climatic Trends and the Distribution of Marine Animals in New England."<sup>43</sup> It was a data-dump, offering little analysis, but an array of incontrovertible facts: air temperatures since 1900 had been warmer than average, and between 1905 and 1949, there had been a trend of warmer winters and milder summers.<sup>44</sup> "For many years," the authors wrote,

Americans have commented on an apparent warming of their climate; older people have referred to the "old-fashioned winters" they once knew. Climatologists long shrugged off the idea as

unfounded, but a melioration in climate is no longer confined to the popular mind: a decided trend toward warmer winter during the past 50 years is now well-documented.

By the time of the report, that trend had actually begun to reverse. In 1960, fishermen were complaining about scarcity of lobster, and coastal fisheries were icebound during the winter months.<sup>45</sup> The creeping cold was met with even more panic and negativity than the runaway warming had been. In the 1990s, climate researchers began to chart sea surface temperature in the North Atlantic, records for which only go back about a century and a half. They found a pattern of seventy-year oscillations between warmer and colder than average periods—a natural climate fluctuation that, they argued in *Nature*, had obscured the signal of warming from the greenhouse effect.<sup>46</sup> Tree ring data has provided evidence that these cycles of warming and cooling have been going on in the Atlantic since the sixteenth century.<sup>47</sup>

Rather than creating nuance in the discussion of climate change, the evidence for natural oscillations in climate was exploited by global warming skeptics, and the Atlantic Multidecadal Oscillation (AMO) became a byword for climate denialism. Micheal Mann, the climatologist who first named the AMO, later admitted that he felt he had “helped create a monster.”<sup>48</sup>

“Depending on who you talk to, some people might think that sort of long-term climate change is a bigger issue, or shorter-term decadal variability is a bigger issue,” Jon Hare, director of the Northeast Fisheries Science Center, tells me. Regardless, both phenomena are happening in tandem. The runaway warming of the gulf, and the 99.9 percent figure, could be read as an amplification of the Atlantic’s natural cycles by the greenhouse effect. If 2012 was the AMO’s peak, the gulf could be headed for a cooldown.

The reassuring prospect of cooling isn’t the aspect of the AMO that preoccupies Hare. Rather, it reveals a shortsightedness, and an amnesia, in the institutions he’s part of, which supply the best available scientific data with which to manage fish stocks in the Northeast. “That idea of ecosystems being variable and changing kind of slipped away,” he says. “We can’t let the opportunity to make management more adaptable slip away. We had an opportunity in the late fifties, early sixties, but as a society, as a profession, as a region, we didn’t take advantage of it.”



Even on the gulf’s current trajectory, there are avenues of return, and changes in the system that can be undone.

The watershed of the gulf is larger than the gulf itself, encompassing the entire state of Maine, much of New Hampshire and Massachusetts, and half of New Brunswick and Nova Scotia. As the effects of climate change have made themselves apparent in the gulf over the last decade, this landscape has been undergoing a reversal of changes that were made over a century ago. Through the eighteenth and nineteenth centuries, some 3,000 of the rivers and streams that feed the gulf were dammed for hydropower, fueling mills and factories.<sup>49</sup> Now, those dams are being strategically removed, restoring spawning access to smelt, alewives, salmon, and herring—all fisheries that had diminished to historic lows. These restorations are being carried out by volunteers, and it’s a network of citizen scientists that monitor the return of the fish, standing at the stream’s edge with clickers to count them as they race by.

Last spring, Moffet drove out to Walker Pond, near Lydia’s bakery, to see the alewife run. The fish make their way up the Bagaduce River, using a fishway to skirt the old dam at the head of the pond. Every year or so the Department of Transportation removes a beaver dam with a backhoe so that the fish can complete their journey. Moffet wasn’t the only pilgrim. “There

were ten blue herons lined up, there were ten ospreys lined up, there were ten bald eagles, just sitting in trees in rows waiting,” he told me. “And the stream—which wasn't any wider than that rug—was jet black as far as you can see down there. Solid wall-to-wall fish, fighting against the current to come up into Walker's pond.”

At the end of our conversation, Moffet lets me in on a secret. “I'm a big fan of codfish,” he says. “And one thing we're seeing on the increase is way more codfish this year. Really a lot more codfish.” We stand over the chart, and he points. “I'm catching codfish just outside of the islands kind of southwest of Stonington.”

It is too soon to say whether the anadromous fish, and the cod, have returned only to be beat back by a warming gulf. But Moffet sees a fighting chance in the success of these conservation efforts, if only people can change the way they conceive of the connection between land and sea. “The stuff that we're talking about going on with the fish in the river and the ocean, it's kind of quiet, separated from people's lives, and they don't see it happening,” he says. It may be that the most important change precipitated by global warming is the way we reengage with the natural world once we can no longer coast on its abundant resources. In order to profit by the ocean again, we will have to truly understand its systems, and where we have broken them.

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<sup>3</sup> Larry Moffet, in conversation with the author in Deer Isle, Maine, January 2020.

<sup>4</sup> Larry Moffet, in conversation with the author in Deer Isle, Maine, January 2020.

<sup>5</sup> Goode et al., "The Brighter Side of Climate Change."

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<sup>17</sup> Bourque, *The Swordfish Hunters*.

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<sup>28</sup> Pauly and Jacquet, *Vanishing Fish*.

<sup>29</sup> "Historical Maine Fisheries Landings Data."

<sup>30</sup> Abel, "Vital to the Region's Waters, Kelp Suffers as the Gulf of Maine Warms."

<sup>31</sup> Anecdotal, according to Steneck.

<sup>32</sup> "Lobstering Offshore Becoming Attractive to Some."

<sup>33</sup> Record and Thompson, "Rapid Climate-Driven Circulation Changes Threaten Conservation of Endangered North Atlantic Right Whales."

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