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The Oldest Forest

Lucy Jakub
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The promise and pitfalls of commercializing kelp.

Reviewed:

Slime: How Algae Created Us, Plague Us, and Just Might Save Us
by Ruth Kassinger
Mariner, 320 pp., $16.95 (paper)

Eat Like a Fish: My Adventures Farming the Ocean to Fight Climate Change
by Bren Smith
Vintage, 303 pp., $16.95 (paper)

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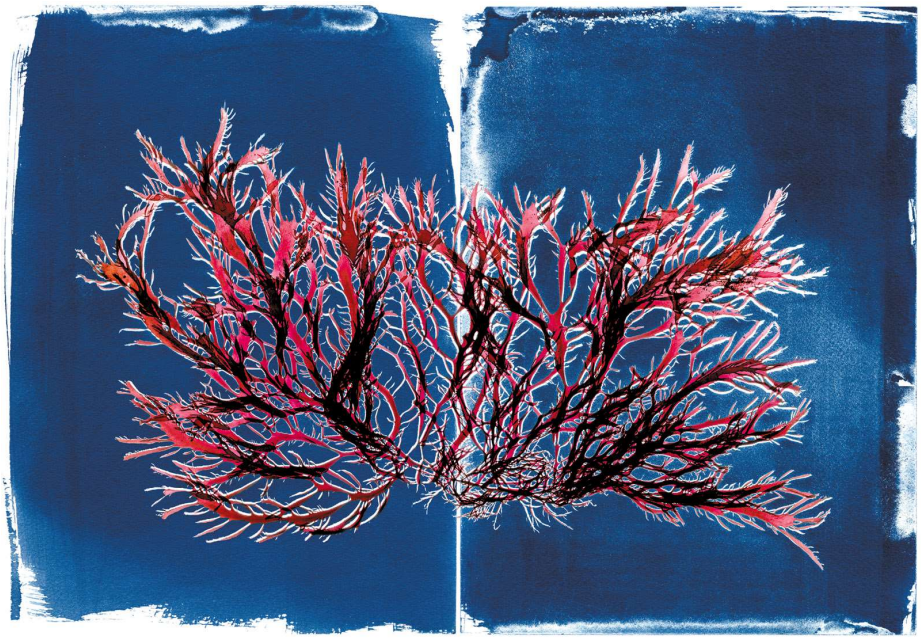

Josie Iselin

Pikea californica; scan overlaid on cyanotype by Josie Iselin, from her book *The Curious World of Seaweed*

In periods of collapse, we're compelled to do things differently as old ways become untenable. We've entered the planetary-tantrum phase of climate change, and fossil fuels cannot be abandoned soon enough. Many people have sworn off disposable plastics and meat, but these are just the first and easiest abnegations: soon, even growing food in the ground will be widely impractical. The earth's breadbaskets have begun to experience devastating patterns of intense drought and flooding, while the global population is expected to grow by two billion over the next thirty years. Crises also lead to a search for silver bullets, in the hope they can be averted without unimaginable sacrifice

—and in this spirit of optimism there has recently been a proliferation of books on algae that take, as one author puts it, an "algal-centric perspective" to envision solutions to the climate crisis.

Our terrestrial biases have long led us to seek beauty and utility first in the plant kingdom, but algae—which are not plants, and span multiple kingdoms—do the essential things that plants do, only better. In order to live on land, plants evolved complicated plumbing and energy-intensive seeds, sacrificing the efficiencies of living directly in the sea. Algae never left the primordial soup. They photosynthesize with every cell and reproduce exponentially.

We owe our atmosphere to algae. The oxygen waste released by cyanobacteria, which evolved photosynthesis 3.7 billion years ago, poisoned most of the anaerobic organisms that had taken hold in the primeval ocean and induced a 300-million-year ice age, setting the terms for all ensuing life. Ruth Kassinger writes in *Slime: How Algae Created Us, Plague Us, and Just Might Save Us* that these primitive algae, "innocuous in the singular and extraordinarily powerful in the unfathomable many, had first conquered and then killed a living planet."

In a fateful encounter, a cyanobacterium was engulfed by a eukaryote, a cell that had evolved the capacity for internal organs, and lived on within its membrane. The cell divided, and the cyanobacterium divided too, and was passed down as vestigial engines for photosynthesis—chloroplasts—in an array of single-celled microalgae, which today include such complex forms as silica-shelled diatoms and the swimming dinoflagellates that prey on them. They eventually made their way into some of the earliest multicellular life: macroalgae, or the seaweeds. Fossils discovered this past February indicate that seaweeds arose over one billion years ago.

That act of radical rearrangement, endosymbiosis, has occurred several times in the evolutionary history of algae, resulting in three major lineages that share important qualities (chief among them, sliminess) but are as distantly related as you are from a mushroom. In 1841, long before endosymbiosis was understood, the great Irish phycologist William Henry Harvey quite accurately distinguished these lineages among the seaweeds, which differ in their reproduction and cellular structure, by color: the chlorophyll-packed green algae that thrive in the shallows and in freshwater, and were precursors to plants; the deep-dwelling red algae often shaped like fans or flowers, and sometimes crustose like corals; and the large, brown, gas-bladdered kelps, tangled wracks, and free-floating *Sargassum*.

To make sense of these differences, Kassinger, a popular-science writer whose previous books are on gardening and botany, packs an impressive amount of biochemistry into digestible terms. In *Slime*, algae are "alchemists," "engines that turn carbon dioxide and water

into a huge variety of organic compounds under an enormous range of conditions," with a litany of applications as biofuels, bioplastics, fertilizers, reef-safe sunscreen, vegan butter, anti-aging serums, and dietary supplements. Incinerated, kelp yields potash, used for the manufacture of soap and glass; fermented, it becomes crude oil. Certain seaweeds when fed to cows nearly eliminate methane from their flatulence, offering a way to curb the equivalent of 15 percent of anthropogenic carbon dioxide emissions; used as a fertilizer, kelp stimulates the growth of fungi that help roots absorb water and phosphorus.

Coastal people have been feeding seaweed to their livestock and spreading it on their fields for millennia and eating it for even longer. Seaweeds are half protein, and more saturated with vitamins and minerals than kale. The Incas and First Peoples of the Pacific Northwest ate and traded algae, which was easily dried and preserved, and the Aztecs made cakes from cyanobacteria. The Vikings ate leathery purple dulse. The Irish planted potatoes in beds of wrack, and when the potatoes failed, they survived on *Chondrus cripsus*, or Irish moss. The red seaweed *Porphyra*, known in Wales as laver, is traditionally cooked into a jelly, kneaded into dough, and fried in lard. In Japan it is made into an edible paper, and in ancient times nori was a currency between tribes and was offered to the gods in Shinto rituals; over 10,000 years, the gut flora of the Japanese have uniquely evolved to digest red seaweeds.

Kassinger wades into a speculative theory, proposed by the nutrition and brain scientists Stephen Cunnane and Michael Crawford, that a diet of algae was crucial in early human evolution. They propose that when hominins left the forest for the marshes of the Great Rift Valley, in East Africa, they would have eaten reeds, insects, and fish laced with DHA and iodine, two nutrients abundant in algae that are critical for the development of large brains. When the spread of glaciers 165,000 years ago forced *Homo sapiens* in Africa to migrate, a community settled in Cape Agulhas at the southernmost tip of the continent, where they would have been nourished by plentiful marine life. Many archaeologists, meanwhile, have adopted Jon Erlandson's hypothesis that Stone Age humans settled the Americas not by traversing the Beringia land bridge but by navigating in boats a "kelp highway" of whales, seals, fish, and seaweeds hugging the Pacific Rim.

The cultivation of seaweed eluded its most ardent consumers until the 1940s. Japanese fishermen had encouraged nori to grow on bamboo staked in the ocean, but the harvest was fickle from year to year. The modern seaweed industry, today worth $6 billion and centered in East Asia, was enabled by the research of a British biologist, Kathleen Drew-Baker. In 1949 she published a small paper in *Nature* showing that the life cycle of *Porphyra* involves not one but two reproductive stages: immature seaweed rides out inclement weather in the sheltered deep and releases spores that settle closer to shore when

conditions are right. Japanese scientists, in the midst of famine in US-occupied Japan, learned to pre-seed lines of nori in the lab and bring them to the ocean to grow.

Kassinger visits sprawling nori farms in South Korea, where giant sacks of it are sold at auction and carried away in dump trucks. This, she thinks, is a fine model for commercial seaweed production in the US. But back home she finds a movement to farm kelp on a small, decentralized scale, and people who are fiercely opinionated as to who should harvest it, and where, and how. A better guide to the politics of seaweed is Bren Smith, a reformed commercial fisherman who now farms kelp and oysters. In *Eat Like a Fish*, part memoir, part do-it-yourself handbook, he offers kelp as a means to environmental and economic justice for imperiled fishing communities.

Smith rents a parcel of water in the Long Island Sound (at the heart of seaweed politics is the fact that water can't be owned, but must be shared). His kelp is a no-input crop, needing no fertilizers other than the nitrogen and phosphorus that already pollute coastal waters and otherwise promote blooms of microalgae, which can be toxic. Such blooms become like gas bombs when they die and are decomposed by bacteria that deplete the water of oxygen. Seaweed releases oxygen while the sun shines, alleviating ocean acidification and attracting fish, which in turn attract seabirds. Oysters and mussels suspended in bags, and clams seeded in the mud below, filter nitrogen and particulates from the sound (there is an ongoing project to restore New York Harbor's once-famous oyster reefs for this purpose—though in such polluted waterways shellfish are also magnets for heavy metals, and shouldn't be eaten). Smith did not invent this model of ocean farming—he credits Chinese carp farmers and Roman oyster farmers—but it took him years to discover and perfect it as a livelihood. His nonprofit, GreenWave, helps to establish such farms on both coasts of the US.

The creation of GreenWave is the triumphal climax of the book. Smith grew up in Newfoundland and caught his first cod when he was four. After his parents "shanghaied" him to suburban Massachusetts, he dropped out of high school, narrowly evaded juvenile detention, and found work on a lobster boat. From there he joined a commercial ship in Alaska, pulling twenty-hour shifts trawling for Pacific cod. All the young Newf wanted was to be close to the ocean—a desire that, as Smith characterizes it, was basically a death wish. Over the course of *Eat Like a Fish*, he goes partly blind from deck-swabbing chemicals and cracks his skull in a boat-related construction accident (he wakes up from brain surgery with a severe allergy to shellfish). These and other injuries accompany a series of personal and professional failures, some self-inflicted and others named Sandy and Irene.

Haunting *Eat Like a Fish* is the worldwide collapse of fisheries. The biggest blow in the Northeast was the bottoming out of Atlantic cod, fished down over the course of the twentieth century. Cod was protected with stringent quotas beginning in 1990, but the prodigious schools never returned—a loss that is now partly ascribed to climate change. "There was a brutality to it," Smith writes of the cod moratorium in Newfoundland: "thousands of boats beached, fish plants shuttered, kids banned from tossing a line off the docks, retired old-timers barred from jiggin' in their double-ended dories."

Spooked by the consequences of overfishing, Smith went to work for a Newfoundland aquaculture company. This was even spookier: "The mutants we grew were neither fish nor food," he writes. "Turned out my day job was a microcosm of the dark industrial future of ocean agriculture." Initially purported to be a sustainable alternative to wild-caught fish, aquaculture is notorious for using the worst practices of industrial agriculture in the sea: animal overcrowding, poor waste control, and liberal use of hormones and antibiotics. Escaped fish often impart parasites and modified genes to wild populations. Kassinger visits a couple of land-based aquaculture plants that have largely reformed this model by confining fish in recirculating tanks, but such farms aren't paths to food security, only satisfying a first-world hunger for salmon and tuna that require a diet of smaller fish taken from the wild.

If you conduct your shopping with the aim of reducing carbon emissions, it is far better to eat fish than animals raised on land and fed corn. But fish in most parts of the ocean are existentially threatened by warming waters and overfishing. Suppose we could all be eating, without guilt, fresh heaps of nutritious, delicious seaweed? It took a host of celebrity chefs and his wife to teach Smith, a connoisseur of the gas station sandwich, how to eat his own crop of kelp, marinated in barbeque sauce and stripped into "noodles." (He and Kassinger include a number of recipes in the back of their books.) He declares it good—but notes that although Americans are growing more adventurous in their cuisine, they are behind the curve in developing a taste for algae. While countries in East Asia went into full-scale production of seaweed for food after Drew-Baker's breakthrough, the US only considered its industrial applications.

A domestic seaweed rush at the start of the twentieth century was precipitated by the fertilizer industry's dependency on German potash, and US manufacturers were soon fermenting kelp to produce acetone for British munitions during World War I. Chemists known as the "pudding boys," at Kelco in San Diego and Marine Colloids in Rockland, distilled alginate from giant kelp and carrageenan from Irish moss—the latter long used to thicken desserts—to stabilize paint, toothpaste, beer, shampoo, and shoe polish, and were largely responsible for the cornucopia of processed foods that flooded American supermarkets after World War II. During the oil embargo of

the 1970s, the US military developed plans for a thousand-acre seaweed farm in the Pacific, a never-built floating plastic "Hemidome" outfitted with huge propellers to stir up cold water and nutrients from the deep that would provide biofuels and petrochemicals for weapons. The first industrial seaweed farm in the US was funded by the Department of Energy and General Electric, and was much mocked in the press before the whole thing was washed away in the El Niño of 1983.

Kassinger became interested in algae in 2008, when the price of a barrel of oil rose to $160. A handful of biofuel startups raised millions in venture capital to grow microalgae in plastic sacks and saltwater raceways in the desert. Growing algae is easy. Genetically engineering algae to store more energy in burnable fats is not easy, but possible. Juicing the tough cells for their oil is the hard part, and the process has remained far too expensive for algae fuel to become competitive with fossil fuels or corn ethanol. In 2012 the companies Solazyme and Sapphire supplied algae fuel to the destroyers and strike aircraft of the US Navy's Great Green Fleet, a stunt by the Department of Defense to untether itself from foreign oil.[1] Two years later, the rise of fracking killed both companies.

Today, algae fuel is little more than a greenwashing scheme for ExxonMobil, which features the chartreuse sludge heavily in its ads but in the past decade has spent $1.2 billion more on advertising than it has on biofuel development, while declining to invest in renewable energy sources. Kassinger holds out hope that the advance of technology and government subsidies will someday produce a feasible alternative fuel, but what seems clear from her own telling (her account of algae plastics is similarly dispiriting) is that we can't rely on industries of scale to quickly spread green fixes. Nor is kelp, despite clever marketing, an inherently "virtuous vegetable." Merely continuing our cycles of consumption and waste with different ingredients will not heal the environment. Kelco, which once carefully monitored the sustainability of its kelp harvest and the waste of its factory, was taken over by Merck and then Monsanto, and by the 1990s it was the subject of an EPA lawsuit for contributing more than a third of San Diego's industrial smog.

Smith denies that he's an environmentalist; he believes that the environmental movement has abandoned the needs of the working class. But he shied away from Wall Street investors who took an interest in GreenWave. "I farm vertically," he writes, "but you'd never catch me running my business that way." His version of a kelp utopia is a coastal network of small independent ocean farms, supplying food locally and sustainably. The pandemic has only further illustrated the weaknesses of global supply chains, and the need for jobs that can't be so easily taken away.

Kassinger and Smith assume that their readers have, if not distinctly unpleasant associations with algae, a starting indifference. But before algae could seduce entrepreneurs and biotech companies, it was necessary that someone fall in love with this group of "humble" organisms for utterly human reasons. When their categorizer William Henry Harvey was only fifteen, he proclaimed his rebellious interest in the nonflowering "plants":

> I intend to study my favourite and useless class, Cryptogamia. I think I hear thee say, Tut-tut! But no matter. To be useless, various, and abstruse, is a sufficient recommendation of a science to make it pleasing to me.

Josie Iselin's *The Curious World of Seaweed* is a series of interconnected essays that revel in the aesthetics of seaweeds and the people, like Harvey, who have studied them. Iselin, an artist and "kelp ambassador" for her local beach conservancy in California, couldn't care less about kelp plastics or fertilizers. With a flatbed scanner she turns foraged Pacific seaweeds into vibrant collages layered with early scientific illustrations, capturing in all their glory the strange, diverse forms that enchant naturalists: filigreed colander kelp, glittering dead man's fingers, the emerald cellophane of sea lettuce.[2]

The prevailing disdain for algae opened up the field early on to women, who have contributed much of what we know about their biology. "Sea-weeding" was, by the 1860s, a popular pastime of women in Britain.[3] Cryptogams lacked titillating sexual organs (it was also the era of the "fern craze") and were considered too primitive by most professional botanists to be worth serious study. Iselin works in cyanotype, a medium pioneered by Anna Atkins in her 1843 monograph *Photographs of British Algae: Cyanotype Impressions*.[4] Drew-Baker, a century later, carried out her research on red algae after losing her university position when she married. It was, finally, the American biologist Lynn Margulis who advanced the theory of endosymbiosis, for which she was widely ridiculed at the time.

Iselin also traces the impact on kelp of the Pacific fur trade, which began when Georg Steller's Russian expedition brought back sea otter pelts from the Aleutian Islands in 1741. The Scottish naturalist Archibald Menzies collected feather boa kelp off Vancouver Island while his shipmates skinned otters. By 1900, otters had been all but exterminated from the Pacific coast. The ramifications of this loss were not fully apparent until 2013, when a marine heat wave in the northeastern Pacific introduced a wasting disease among sea stars that, along with otters, were the major predators of sea urchins. In only the past five years, 90 percent of Northern California's bull kelp has been chewed to rubble by an unchecked urchin scourge—a transformation that is nearly impossible to reverse.

A small colony of otters was discovered in Point Sur in the 1930s, but reintroduction to their former range has been hindered by toxic algal blooms along the coast, as well as by the predation of orcas, robbed of their preferred prey, the baleen whales. In Northern California people have also resisted reintroductions, viewing otters as competitors for abalone. This drama, in which our use of resources is pitted against the needs of other species, drives Susan Hand Shetterly's *Seaweed Chronicles: A World at the Water's Edge*. While acknowledging, as Smith does, seaweed's potential as a lifeline for fishing communities, she asks what this commodification means for the ecosystems held together by algae.

Shetterly lives in Maine, a state with more miles of coastline than California, if you count Maine's islands—ample substrate for *Ascophyllum nodosum*, or rockweed, a shaggy golden-green wrack. She wades through muck and crawls through poison ivy to spy on the myriad species that share the intertidal zone: sandpipers, petrels, periwinkles, brine shrimp. All depend, for some part of their lives, on the rockweed for food or shelter. Shetterly writes in the tradition of Rachel Carson, who meticulously described this coast and its seaweeds in *The Edge of the Sea* (1955). While Carson cataloged rich biodiversity, Shetterly's story is one of loss, uncertainty, and invasive green crabs, consummate clam diggers that also find shelter in the wrack.

She tramps through the human ecosystem as well, visiting kelp farms and interviewing economists, ecologists, and marine policymakers. Anyone who has ever dipped a toe into New England fisheries knows how contentious, and wickedly complex, any discussion of marine extraction can become, and Shetterly is a circumspect but sensitive guide. *Seaweed Chronicles* and *Slime* quote several of the same sources, but while Kassinger is eager to see marketable results (and bewildered by the rustic lifestyle of Maine's seaweed foragers), Shetterly lets them talk for pages about fisheries management and conservation. She shares Smith's emphasis on environmental justice: "Coastal people need jobs that require of them the sort of skill that the old fishermen once had," she writes, but warns that "the jobs won't come unless what's left in our bays and deeper oceans is vigorous and plentiful."

The catalyst for *Seaweed Chronicles* was the expansion of a Canadian company, Acadian Seaplants, into Maine waters to harvest rockweed, which it processes into liquid fertilizer and animal feed. Twenty-three million wet pounds were landed in 2018, enough to cause alarm among environmentalists who fear that harvesting even small amounts will spell disaster for the eider ducks that shelter in it; eagles, hard up for fish, have developed a taste for ducklings. One of the marine biologists Shetterly interviews asks, "Should we be harvesting habitat? Is that really what we should be doing?"

She has no easy answer—only that we need to "build a new model of how to manage ocean resources that doesn't edge them toward oblivion." She notes a human pathology of seeing abundance in nature and coming up with ways to exploit it. In a world of depleted resources, anything that still thrives will lure industry. Kassinger writes that "there are more algae in the oceans than there are stars in all the galaxies in the universe"; a harvester in Maine exclaims at a town meeting, "Rockweed—you just can't overharvest it. You can't. It's infinite!" People once said the same of cod. In 2013, in a hopeful and unprecedented move, Maine harvesters actually requested a state management plan for rockweed.

That plan was put on hold, as a smaller kelping company brought a lawsuit against Acadian. In March 2019, after *Seaweed Chronicles* was published, Maine's Supreme Court ruled that the intertidal zone may only be foraged with the permission of the coastal landowner. This closing of the commons threw the rockweed industry into limbo. It was a perverse victory for conservationists, codifying the gentrification of the coast, which grows ever less accessible to the people who make their living from the sea.

Yet the true threat to the rockweed is warming in the Gulf of Maine, by some measures the fastest-heating corner of the world ocean. Shetterly is faced with the dilemma Alan Weisman has articulated in these pages, that books, while vital to convey the complexity of ecosystems, are too cumbersome to keep up with the gathering effects of climate change[5]—as she puts it, "what is left is changing even as we try to understand all the small and large parts and how they fit together."

Charles Darwin recognized the vitality of kelp forests when he visited Tierra del Fuego, the crumbled archipelago at the terminal of Erlandson's kelp highway:

> I can only compare these great aquatic forests of the Southern Hemisphere with the terrestrial ones in the intertropical regions. Yet if the latter should be destroyed in any country, I do not believe nearly so many species of animals would perish as, under similar circumstances, would happen with the kelp.

These fears have come to pass. Since the 1970s 38 percent of kelp forests around the world have experienced marked declines, most of them scorched by marine heatwaves, but some stunted from overharvest or ravaged by invasive species.

At the same time, warming unleashes chaotic growth, and Kassinger writes that "with mankind in the mix, algae are operating at warp speed." Every year, fertilizers washed down the Amazon River fuel a monstrous lei of *Sargassum* that stretches across the Atlantic and rots on Caribbean beaches. Warm, wet winds off the melting Himalayas

have caused the circulation of the Arabian Sea to stagnate and the water to bloom with dinoflagellates, destroying the region's fisheries. In Maine, lobstermen haul traps snarled in a dense red algae they call "gorilla hair" that likely arrived in the ballast of a ship from Japan; such low-lying seaweeds often move in where kelp canopies have withered, turning forests into fields. "Ecological succession, the process by which the structure of a biological community evolves, comes to mind more frequently in our new era of increased forest fires," writes Iselin, considering the ways in which heat and human activity are transforming marine flora. "What grows back is not necessarily what burned."

Kelp forests naturally sequester some 11 percent of their carbon in the deep sea, and scientists have proposed that seaweed be grown on an industrial scale and sunk to the bottom of the Pacific. In another carbon-trapping scheme, geoengineers seeded the Southern Ocean with iron to encourage the growth of diatoms, which, having heavy shells, sink more readily than other phytoplankton (whale feces remains a much more effective fertilizer). But algae are a slimy lifeline. To take an algal-centric perspective is both to acknowledge that there are organisms with greater transformative power on this earth than humans, and that they cannot necessarily be harnessed for our benefit. Like Shetterly, Iselin is ambivalent about the race to turn algae into profit, or to invest too much hope in the kelp utopia. She advises us to "leave the algae alone to do their own thing, heal our oceans as they can, and let them be, as the profound ecological engineers that they are, not another resource for us to figure out how to manage." According to Kassinger, we can count on algae to cool the hothouse earth, but only "in the long, long run."

When I moved to Venice Beach in May, the Southern California Bight was in the throes of the biggest red tide in memory. Heavy rains in March had sent city runoff into the unseasonably warm bight, and for weeks the waves were muddy with dinoflagellates. Word spread that it was better to visit the beach at night. In socially distanced groups, locals gathered to watch blue shocks of the bioluminescent algae course through the breaking waves. It is one of the most beautiful things I've ever seen. Weeks later, Orange County beaches were strewn with fish suffocated by the decaying bloom. People will admire such displays long after the fish have departed and fronds of kelp have ceased to wash up on the sand, evidence of an underwater forest.

Lucy Jakub

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1. By 2016 the Great Green Fleet was cutting its marine diesel with beef tallow. ↩

2. For readers less interested in science than seaweed aesthetics, the Dutch artist Miek Zwamborn's *Seaweed: An Enchanting Miscellany* (Greystone, 2020) meanders beyond the genre of scientific illustration and catalogs the presence of algae in art, literature, and film. ↩

3. Amateur naturalists did much for the burgeoning taxonomy of seaweeds, but did not tread lightly in the field; Edmund Gosse, the son of Philip Henry Gosse, who popularized the home aquarium, lamented in 1907 that "an army of 'collectors'" had "ravaged every corner" of the

4. See Luc Sante, "Early Developments," *The New York Review*, May 9, 2019. ↩

5. See Alan Weisman, "Burning Down the House," *The New York Review*, August 15, 2019. ↩