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Introduction

Entangled

Monterey Bay, California's giant kelp forest is a wilderness just off its famous aquarium. *Photo credit: Monterey Bay Aquarium*

"Sea-weed sways and sways and swirls
as if swaying were its form of stillness
and if it flushes against fierce rock
it slips over it as shadows do, without hurting itself."
—D. H. Lawrence, "Sea-Weed"

So let's begin a journey through one of the largest marine habitats on Earth, a wilderness bigger than the Amazon rainforest, a cold and challenging saltwater realm that can also be an entrancing cathedral of light and life, a vibrant center of wonder and warning in our rapidly changing seas. The world's kelp forests are as mysterious as the deepest ocean trenches even though they cover the nearshore waters of close to one third of our global coastline.

Hundreds of millions of people live within a shore dive's distance of kelp forests without knowing much or anything about them. Seeing mounds of pungent, fly-swarmed seaweed on the beach, few recognize that the kelp beds from which it may have detached also provide half a trillion dollars of goods and services a year. These range from edible marine wildlife to emulsifiers used in ice cream and cosmetics to powerful storm and coastal protection and even much of the oxygen we breathe. It turns out kelp forests are one of the essential sources and crucibles of life on our blue planet. Welcome to their story.

The water is an amazingly clear but chilly 54 degrees, with the stalks of the giant kelp more evenly spread out than during my last dive. At 15 feet below the surface, I stop to admire some of their brown fronds and pearl-like floats and how they form semicircular patterns as seven leopard sharks circle us at a distance. My dive buddy and I drop to the sandy bottom 28 feet down, passing a 150-pound female black sea bass. The rocks and boulders at the bottom include a thick understory of sugar kelp and southern sea palm. My dive buddy leads me to a small cave where three wolf eels are tucked in, two staring out unblinkingly with soft, fleshy, gray, thick-lipped, and snaggle-toothed disinterest. A gray and red sheephead cruises by. I lie down in the sand and have a friendly stare-off with a big, brown spiky-finned rockfish. Other rockfish are hanging vertically on walls and boulders while a school of opaleyes graze on short red seaweeds. Higher up in the water column

a school of northern anchovies are flashing silver. There's a fat abalone that I watch twist its shell like a top. The huge sea bass gets curious. She comes right up to my facemask before gliding past, giving me a foggy fish eye. Next, a 5-foot leopard shark slides under me. They're spotted and lovely and completely harmless unless you're a small crab.

A moment later I spot four of the ocean's top predators about 20 feet away. One's pushing a cart. Two of them wave at us. One takes a picture through the thick plexiglass. At 9:30 on this Wednesday morning it's still half an hour before the aquarium staff open the doors to the public. After thirty-seven minutes, staff diver Tori Bartindale-Guffey and I surface and leave the 343,000-gallon exhibit, climbing stairs onto the open topside deck where the big pump, designed by David Packard (co-founder of Hewlett-Packard and father of Julie Packard), moves 1,500 gallons of Monterey Bay Sea water through the exhibit every minute except when it's turned off for scuba diver safety.

Later, inside the main hall, I stand in front of the two-story-high windows of the kelp forest exhibit with dozens of visitors who are also getting to admire its more than 300 species of kelp and more than 1,000 fish, many brought in as spore and larvae by the big pump's waters. The best part, however, is that after seeing this and other exhibits, they can go outside on the aquarium's back deck and view Monterey Bay itself and its natural kelp forest, including today's raft of some twenty sea otters floating just offshore, wrapped in blades of giant kelp.

Giant kelp (*Macrocystis pyrifera*) grows faster than tropical bamboo, about 3 to 5 inches a day inside the exhibit tank and 10 to 12 inches in the bay. On her retirement as CEO of the aquarium in 2025, Julie Packard was interviewed by *The New York Times* and asked what her favorite organism in the ocean was. "It's not an animal, it's a plant," she responded. "Giant kelp . . . is the underpinning of the aquarium." Of course, as a marine biologist, she knew that kelp wasn't actually a plant but a macroalgae, but she also understood her audience would not care for that level of taxonomic detail, given that her interviewer was more interested in her opinion of SpongeBob SquarePants. "He lives in a pineapple under the sea," the reporter prompted. "OK, well, scientifically, that is problematic. It doesn't happen," she responded coolly.

Although it's not a plant, it's easy for people to mistake kelp,

particularly its largest species, giant and bull kelp, for plants because their appearance is so similar in their shared natural architecture (called convergent evolution). The kelp's holdfast that clings to the shallow rocky ocean bottom looks like a complex jumble of roots such as a banyan or oak tree might put down, but unlike plant roots the holdfast provides no nutrients for the kelp but acts rather as an anchor and habitat for countless small creatures. Its stipes are similar to the trunks of skinny trees such as aspens or willows but held up in the water by floats, bubble-like gas bladders filled with oxygen, nitrogen, and carbon dioxide in concentrations similar to the air we breathe. These are called pneumatocysts.

Sugar and ribbon kelp and other shorter seaweeds don't have these floats but let the currents sway them where they will. The giant kelp's stipes support long, branching, leaf-like blades that at the surface can become a thick canopy spread across the top of the ocean, sometimes thick enough for egrets and seabirds to walk across. And although their cell walls are made of cellulose, like trees, they also contain alginate, which has greater uses in food and other human products than does sawdust. Also, you can't eat trees like you can most kelp. One other difference between kelp and trees is that without a strong dose of hallucinogens you won't see 20- to 200-foot-tall trees swaying above and around you on a walk in the woods as you will diving through a kelp forest, even one contained in a major aquarium.

With its focus on kelp forests both inside and outside, the Monterey Bay Aquarium is a uniquely kelp-centric experience for its 2 million visitors a year. Even its logo represents the tip of a kelp frond. And as long as cartoon characters such as SpongeBob have entered the narrative, the aquarium also served as the model for the Marine Life Institute in the second Finding Nemo movie, *Finding Dory*.

Another aquarium that also has some two million annual visitors is the Shedd Aquarium in Chicago. Inside, on a wintery day with thousands of paying visitors, there is a long, winding line of hundreds of people waiting to get onto an elevator for the Wild Reef exhibit with its big shark tank. The line extends through part of the old section of the aquarium from 1930. At the far end of a venerable gallery bracketed with small aquaria including exhibits of seahorses, leafy seadragons,

and a giant Pacific octopus is their kelp forest display. About 30 feet wide, 10 feet high, and 13 feet deep, it includes realistic-looking synthetic giant kelp and is home to jack mackerels, starry flounder, leopard sharks, purple urchin, and a few orange garibaldis; on a lower level is a two-story sea otter display.

At 4:30 p.m. Grace Patterson, one of the aquarium's public engagement facilitators, announces her talk: "I'll be giving my kelp forest chat so you have something to learn and be entertained by while waiting on line for the Wild Reef exhibit." Along with the serpentine crowd, five people sit on a bench facing the exhibit as she explains that the display is supposed to be "Monterey Bay Harbor" and how kelp is not a plant but an alga that likes cold water and how it "may not survive because of the changing ocean." By the end of her talk her immediate audience has grown to eight. Half an hour later 1,000 people will attend one of the regular Pacific white-sided dolphin "presentations" (they don't call them shows) with synchronized leaps and tail walks in Shedd's Oceanarium amphitheater.

Kelp is generally not thought of in the same way as coral reefs, sharks, or dancing dolphins. Actually, it's rarely thought of at all. So don't worry if you haven't heard of the Great African Sea Forest, where *My Octopus Teacher* was filmed, or Australia's Great Southern Reef, which is more than three times longer than the Great Barrier Reef, or the Kelp Highway, which stretches from Russia across the Bering Sea and down the west coast of North America to Mexico, or the Sea Forests at the End of the World, whose brown canopy covers the waters of Patagonia and the southern tip of Latin America. You can find similar marine forests in the colder waters of Norway, New Zealand, England, Scotland, Ireland, Iceland, Greenland, Canada, Japan, Spain, Portugal, Korea, Peru, the Galápagos Islands, and the sub-Antarctic Falklands (aka Malvinas).

Although this book is set predominantly in the United States, the challenges that kelp forests face are global. Unlike the burning of the Amazon rainforest or the unprecedented wildfires scorching the planet from Siberia to Los Angeles, the other great forest disaster now taking place on our blue planet, the decline of living kelp forests beneath our seas, has gone largely unreported. And yet at 2.8 million

square miles, kelp forests cover an area larger than the Amazon, bordering and enriching the waters of many of the world's coastlines.

At the same time, kelp forests have declined by as much as 60 percent over the past half century as they've repeatedly been affected by pollution, overfishing, mechanical harvesting, and, increasingly, marine heatwaves that have seen places such as Prince William Sound, Alaska, recording 76-degree water temperatures, as deadly to kelp as the 100-degree water temperatures in the Florida Keys were to reef-forming corals several years ago.

Although many people know the world's coral reefs are in trouble, fewer know that giant marine algae such as bull kelp are facing the biggest threat to their existence since they first evolved more than 32 million years ago. What happens to the seahorses, salmon, lobster, whales, and more than 1,000 other creatures dependent on kelp forests if they disappear? What happens to us? Neither science nor society has figured that one out.

Kelp forests and other large algae (which come in red, green, and brown) are also essential to the regulation of our atmosphere. Along with mangroves, salt marshes, and seagrasses, they absorb vast amounts of carbon dioxide through photosynthesis while generating 20 percent of the oxygen we need to live, about the same amount as all of the world's rainforests. Microalgae, mainly phytoplankton, produce another 50 percent of our oxygen. It only makes sense that algae and marine plants should generate 70 percent of the oxygen we breathe, because the ocean covers 71 percent of the earth's solar-absorbing surface area, almost all of which is rich in photosynthesizing life.

Kelp forests, like coral reefs and salt marshes, are also good for storm protection, grooming waves (we'll get a surfer to explain later), damping down sea surges, and reducing coastal erosion. And yet, along with the deep ocean, the forests the sea are a largely unknown realm, even though you can often spot their canopies bobbing just offshore. Other than the piles of pungent kelp wrack that decay on our beaches, attracting seaweed flies, kelp flies, beach hoppers (sand fleas), and the shorebirds who feast on them, they remain as mysterious to most people as the depths of the Marianas Trench 7 miles below the surface of

the ocean. Unfortunately, out of sight and out of mind is not a useful way to address one of the great conservation challenges of our time.

Some coastal communities such as Fort Bragg, California, are being hammered by the loss of wild kelp forests. "The destruction that's occurring is worse than the fire that burned down my house and 10,000 other homes in Sonoma County" (during the 2017 Tubbs Fire, which actually destroyed 5,643 structures), says Doug Jung, a longtime California abalone diver who used to free dive for red abalone outside Fort Bragg and would then join dozens of friends and family for long evenings of cookouts on the beach. Still, today there is far more global interest in farming kelp than in saving it, even though wild kelp is the "mother seed" for the expanding seaweed aquaculture industry.

That's not to say there isn't good news in the focus on seaweed and kelp for regenerative and climate-friendly food production (more than 40 million tons a year at present), for use as an emulsifier and bonding agent in a wide range of everyday products (e.g., toothpaste, shampoo, and beer), or as a potential source of new products such as clothing, anti-inflammatory drugs, bioplastics, and wound healing gels. But this emerging market sector and the commercial fishing industry, which also depends on kelp, are failing to make the investments needed to save the wild marine forests that are essential to their livelihoods and whose environmental services are estimated to be worth $500 billion a year according to a 2023 study published in the prestigious scientific journal *Nature*.

Also, we're constantly learning of new uses for kelp. If you've ever considered an exfoliant treatment, for example, some orcas have as well. A summer 2025 report in *Current Biology* identified how the southern resident orcas of the Pacific's Salish Sea use loose bull kelp stipes, or cut off 2-foot lengths with their teeth, and place them next to a partner's skin. They then roll the kelp pieces between their bodies. Based on drone observations, this kelp "loofah" treatment suggests that, as crows have already demonstrated, you don't need hands to be an effective tool user. In this case, however, you do need a healthy kelp forest.

The idea that you save what you love is appealing when it comes

to koalas, whales, and coral reefs, but too few of us have immersed ourselves in the ethereal beauty and unique live action you encounter diving in a kelp forest. Why? "It's that cold water. People like to be comfortable. Get in that warm water with the coral," National Geographic explorer in residence Sylvia Earle notes sagely.

And so, other than some Indigenous ones, too few stories tell of the wonders, the creatures, and the people whose lives depend on and are defined by these forests of the sea. And again, what happens if they go away? That's one of the questions we'll try to answer in this book while also introducing you to some engaging people, places, and animals that thrive on this wet and salty frontline of life, profiling its first responders and restoration scientists, artisans and fishing folk, divers and tribal stewards working to save another of our great foundational wonders of the world.

After all, kelp is one of the most resilient and fastest-growing organisms on Earth—capable of growing up to 2 feet a day—even as it faces rapid decline. I've swum through a kelp forest that ten years earlier had been a moonscape-like urchin barren. One California cove full of kelp was wiped out by a landslide but fully recovered within two years. In South Africa, climate change, which generates winners and losers, has had the counterintuitive effect of expanding the range of its kelp forests. In Norway, warming waters have allowed the expansion of urchin-eating crab populations that are helping restore the kelp. In Argentina citizen action has led to the creation of marine parks that protect their healthy wild kelp, and in South Korea thousands of acres a year are being restored by a government fishery agency collaborating with local communities in the largest global effort to date to grow a solution faster than the problem being confronted.

And yet, short of a rapid transition off fossil fuels, which is not happening at this time, you can't really talk about hope for the future of kelp forests that are being pummeled by marine heatwaves but instead may have to focus on saving what's left, with the understanding that kelp forests, although resilient, are now in need of active human intervention. This could mean establishing fully protected marine parks, investing in essential research, and restoring damaged habitat to ensure that healthy kelp forests continue to exist, expand where possible,

and perhaps someday thrive again, as they have for millions of years across the temperate seas of our blue marble planet.

But this will require a commitment to the multigenerational task of ecosystem restoration that also needs to become a major human enterprise and job generator during the remainder of this century and into the next (and the one after) if there's to be any chance of saving the countless species of flora and fauna, both wet and dry, that make up the web of life in which we too are entangled.

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