THE UNDERWATER ANTHROPOCENE

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Scientific dialogues on the Anthropocene rarely extend below the high-tide line. This terrestrial bias is perhaps justifiable, as we have been altering terrestrial ecosystems since the African diaspora gained momentum about fifty thousand years ago. Today, croplands and pastures take up about 40 percent of the earth's land surface, while the forty million miles of road (a distance equivalent to 165 trips to the moon) that we have laid out across the world have left less than 10 percent of the planet's land surface remote. The terrestrial portion of the world has been brought unambiguously under the dominion of our species.

By almost all measures, however, the mark of the Anthropocene has been lighter in the oceans. California, my home, provides an illustrative example. Humans assisted with the extirpation of terrestrial megafauna (e.g., eleven-ton mammoths, ground sloths more than ten feet tall) from the region about fourteen thousand years ago. We then proceeded to drive California's wolves and grizzly bears extinct (the latter our state animal and flag symbol). But today, just offshore and within eyesight of metropolitan skylines, thirty-three-ton gray whales undertake one of the longest mammal migrations on the planet, 550-pound giant sea bass vocalize at divers, and white sharks investigate the palatability of about one and a half California beachgoers annually. While deeply altered, the oceans retain a wildness that has become rare in much of the terrestrial world.

What delayed and muted the arrival of the Anthropocene in the oceans? The simple answer is that it is harder to change the oceans—at least for us terrestrial apes. Examples of nonhuman great apes affecting aquatic ecosystems are uniformly underwhelming: orangutans can catch disabled catfish, and bonobos scoop up the occasional aquatic animal when swamp foraging. But because we humans rely more on our brains than on tooth or claw, we eventually overcame the significant physical barriers that normally prevent terrestrial animals from hunting efficiently in ocean ecosystems. We invented

our first deep-sea fishing technologies (e.g., bone fishhooks) and were catching pelagic fish at least forty thousand years ago. But it wasn't until after the Second World War, when we repurposed wartime marine technologies to industrialize fishing fleets, that we profoundly amplified our impact on the oceans and arguably first wet the feet of our global human footprint.

The International Union for Conservation of Nature (IUCN) recognizes more than six hundred species extinctions on land in the past 515 years, but only fifteen in the oceans. While this pattern genuinely reflects the late start of the marine Anthropocene, measurements of ocean extinction must be viewed as minimum estimates. Just as it is harder to cause extinction in the oceans, it is also much harder to detect marine extinctions. It took us seventy-three years to find the *Titanic* after it sank—and she weighed fifty thousand tons and was perhaps the most famous ship in all of history. It is easy to imagine that a cryptic marine species, such as a flatfish or goby, could go extinct without notice.

Measures of outright global extinction, by themselves, are insufficient barometers of anthropogenic change. Many extant marine species have been massively depleted in number both purposefully (e.g., highly priced and prized bluefin tuna) and accidentally (e.g., sea turtles as bycatch). Precipitous declines in the abundance of terrestrial species such as amphibians, bees, and bats are widely known, but drops of equal or greater intensity have recently been described for marine fauna: seabird species have declined by about 70 percent, numerous sharks by more than 90 percent, and certain great whale species by 80 to 90 percent.

One proposed start date for the terrestrial Anthropocene is about eleven thousand years ago, when key human populations switched from hunting and gathering to farming. A game-changing transition occurred in the oceans in 2014, when it was estimated that, for the first time, humans consumed more fish that came from aquaculture than from the wild. Throughout history, the oceans have served as publicly accessible seafood sections full of free-range meat, but the potential for wild terrestrial ecosystems to regularly provision humanity in this fashion went extinct in most parts of

the planet hundreds of years ago. A repetition of this history in marine ecosystems would represent a radical shift in our relationship with the oceans.

Another transformative change in the Anthropocene oceans is the emergence of the Marine Industrial Revolution: a shift, now under way, from focusing on the capture of marine wildlife for consumption to using marine resources and marine real estate to foster new marine industries. The Marine Industrial Revolution is well exemplified by the explosive growth of marine mining, marine power generation, desalination projects, aquaculture, oil and gas extraction, and coastal construction. While much of this new ocean industry positively stimulates economic growth and helps meet food and energy shortfalls, it also ups the ante on how humans change the oceans. We have graduated from harvesting marine species to harvesting marine habitats.

The Anthropocene palpably manifests itself as colorful flecks in the cod end of plankton nets and in grabs of deep-sea sediment. Plastic pollution has become a near ubiquitous constituent of our modern oceans. We take about five million tons of tuna from the global oceans annually—and put back two to three times that amount of plastic. This plastic is making its way into marine food webs (for instance, it is estimated that 99 percent of seabirds will be swallowing plastic by 2050) and even onto our own dinner plates (25 percent of fish in market surveys contained plastic or fiber debris).

Like all parts of the earth, from rocks to human tendons, the tissues of animal life in the oceans (e.g., shark vertebrae, coral skeletons) were chemically marked by aboveground nuclear weapons testing during the 1950s. Bomb carbon, however, remains only one of a diverse array of indelible signatures of the Anthropocene left in our oceans. Increased industrial activity, for example, has fueled dramatic and potentially deleterious increases in the mercury levels of top marine predators, including albatross, whales, and seafood-eating humans. The 2011 Fukushima nuclear accident, too, marked a vast section of the Pacific with its eastward-dispersing chemical fingerprint. The raw power of humanity to write our history into the very bodies of marine life and the essence of the waves is impressive—and deeply disconcerting.

Nothing happens fast in a 352-quintillion-gallon water bath—and still we have begun to alter basic physical elements of the global ocean. Human-caused climate change is having well-known effects on ocean temperature, acidity, and sea level state, but it is also predicted to exacerbate ocean deoxygenation, perturb coastal upwelling, and alter patterns of ocean circulation. A steadily rising Anthropocene ocean that is hotter, harder to breathe in, and more acidic presents obvious challenges to the future of marine life. The Anthropocene has definitively begun to wash from the land into the oceans, and although its arrival has been delayed and its effects are still less intense there, humanity has already fundamentally altered the ecology, chemistry, and physics of the oceans.

As the first impacts of the marine Anthropocene come into view, so too do the first consequences of living with an altered ocean. Climate-induced shifts in oceanography and weak governance will disproportionately degrade fisheries in poor tropical regions where access to highly nutritious marine foods is just barely keeping myriad malnutrition diseases at bay. Loss of marine wildlife has been linked to increases in insidious social injustices, such as human trafficking and piracy. Degradation of ecosystems also imperils the sustained provisioning of the $2.5 trillion in goods and services that come to us yearly from the oceans.

Is there reason to be optimistic about our potential to constructively engage the arrival of the Anthropocene in the oceans? Definitively yes. Emerging marine industry can be intelligently managed to provide clean energy and new resources without deleteriously usurping ocean ecosystems. Prudent management of wild fisheries can ensure that we can have our marine biodiversity and eat it, too. If we meaningfully follow through on recent groundbreaking global promises to slow climate change, we can buy ocean animals time to adapt to a changing ocean.

It is precisely because the Anthropocene has only just begun in the oceans that we retain a hopeful, meaningful, and valuable opportunity to control how it evolves. The inextricable links between human health and ocean health dictate that much will be determined by how we decide the Anthropocene will unfold in the sea.