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edited by

MARTIN **GUTMANN**

DANIEL **GORMAN**

BEFORE THE U.N. SUSTAINABLE DEVELOPMENT GOALS

A HISTORICAL COMPANION

Before the UN Sustainable Development Goals

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A Historical Companion

Edited by

MARTIN GUTMANN
DANIEL GORMAN

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Complex problems can rarely be understood or solved with the tools of a single academic discipline. The issues at the heart of the UN's Sustainable Development Goals are no different. Moreover, the SDGs address problems that, while regional in triggers and impact, are global in nature. These facts are reflected in the diverse group of authors of this volume, among whom all continents and various disciplinary approaches are represented: anthropology, economics, engineering, environmental studies, international relations, geography, water studies, and history. We would like to thank this group of scholars for embarking on this intellectually challenging but, we hope, richly rewarding exercise. Without fail they did so with a spirit of openness, collaboration, and generosity.

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Daniel Gorman, Waterloo
Martin Gutmann, Freiburg im Breisgau
April 2021

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Overview of the 17 Sustainable Development Goals

1. No Poverty
2. Zero Hunger
3. Good Health and Well-being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation, and Infrastructure
10. Reducing Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace, Justice, and Strong Institutions
17. Partnerships for the Goals

More information can be found on the official UN SDG homepage: https://www.un.org/sustainabledevelopment

14

SDG 14 – Exploiting and Managing the Alien and Unseen World below Water

Poul Holm

The problem with the ocean is that we do not see what is below the surface. When we clear land for urban development, when we change agricultural practices, when we cut the trees or kill off the wolves, we see the changes. The environmental history of the land is well documented, and archaeologists and historians have long been able to record and visualize past landscapes. What happens below the sea surface was largely hidden to the human eye until the development of scuba diving and submarine photography in the second half of the twentieth century.

This chapter will first consider the *obvious*, *i.e.*, changes that have been recognized and given rise to management concerns in recent decades. I shall then look at the long history of *poorly understood* human impact on and management of marine life through millennia. The major historical impact by humans on marine life have been extractions (fisheries, hunting) followed by habitat change of nearshore waters.[1] Despite much attention in recent decades to pollution, introduction of alien species, and climate change, these factors have played relatively minor roles up to the present. Finally, I consider the development of *scientific understanding* and *evidence-based management* developing in the last century and a half. The scientific exploration of life below water made tremendous strides forward with global expeditions in the nineteenth century, but it was only in the early twentieth century that marine science and ecology was able to begin modeling abundance and interaction of species, including the role of human intervention.

SDG 14 aims to conserve and sustainably use the oceans, seas and marine resources. The United Nations have selected ten SDG 14 targets: reduction of marine pollution; ocean acidification; restoration of ecosystems; conservation of coastal and marine areas; improving ocean science; ending subsidies contributing to overfishing; supporting small-scale fishers; increasing sustainable fishing; economic benefits; and implementing and enforcing international sea law. It is a telling

[1] Heike K. Lotze, Hunter S. Lenihan, Bruce J. Bourque, Roger H. Bradbury, Richard G. Cooke, Matthew C. Kay, et al., "Depletion, Degradation, and Recovery Potential of Estuaries and Coastal Seas," *Science* 312, no. 5781, 23 Jun 2006, 1806–1809.

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indicator of the challenges to evidence-based policy that for half of these targets there were no available indicator data at the time of writing this chapter.[2] This deficiency reflects a continuing need to develop our knowledge of the oceans, including how the current ocean crisis originated. It may also be a telling indicator that the extraction of life below water for human consumption in recent decades has developed in ecologically as well as financially unsustainable ways.

The Obvious

As much of life below water is not visible to us, humans have responded to problems only when they surfaced. Pollution of the seas by industry, sewers and run-offs turned rivers, estuaries and the nearshore into stinking cesspits that caused localized outrage. Tanneries were a major cause of pollution through centuries and triggered city governments to prohibit and move activities further downstream of rivers, thus rendering problems less visible. Nineteenth-century development of sewage systems helped combat cholera in humans and initiated a process of fertilization of inshore waters that remained largely invisible. Activated sludge systems were introduced in many Western cities in the first half of the twentieth century and decreased the risk to human health,[3] but open sewage systems remain a danger to human health as well as a danger to inshore habitats and marine life in many regions of the globe.

Seaborne transportation of oil began in the 1860s and dedicated oil tankers developed in the 1880s. The invention of "supertankers" in the 1950s in the wake of the closure of the Suez Canal increased the danger of marine oil spills. When the Torrey Canyon oil tanker wrecked off the coast of Cornwall, UK, in 1967 its cargo of 117,000 tons of crude oil caused an environmental disaster that made global headline news. Oil tanker safety measures increased decisively after the Exxon Valdez disaster in 1989 and oil spills from tankers have decreased. The largest marine oil spill ever in 2011, the Deepwater Horizon in the Gulf of Mexico, was caused by an explosion on a drilling rig. When the rig sank, it directly contaminated an area of 6,500 sq km and caused immediate and long-term life and health problems to animals and humans. The company responsible, British Petroleum (BP), paid a fine of $18.7 billion.[4]

The International Convention for the Prevention of Pollution of the Sea by Oil was agreed in 1954. The governance of this and other international conventions remains the responsibility of the contracting state of the flag-carrier, but in 1958

[2] https://sdg-tracker.org/oceans, accessed January 5, 2021.

[3] Jamie Benidickson, *The Culture of Flushing: A Social and Legal History of Sewage* (UBC Press, 2011).

[4] Bill Freedman, Environmental Science, a Canadian Perspective (Dalhousie University Libraries, 2018) https://ecampusontario.pressbooks.pub/environmentalscience/chapter/chapter-21-oil-spills/, accessed January 7, 2021.

the International Maritime Organization was established as a permanent forum to monitor and develop agreements. The London Convention of 1972 banned the dumping of many types of waste from ships and a new and stricter convention came into force in 2006.[5]

The Green Revolution of agriculture in the 1970s was based on lavish use of nitrogen and phosphor, and the runoff caused a dramatic increase in the eutrophication of inshore waters. The impact remained largely hidden to the human eye until fish mortality in marine dead zones due to oxygen depletion began to attract attention and effective counteractive measures began to be introduced in the 1980s. However, eutrophication continues to increase in many regions of the world.[6] In the last couple of decades marine litter, particularly plastic, has given cause for concern. An international Coastal Cleanup report of 2013 identified that seven out of the top ten debris items in the sea are plastic such as cigarette butts, food wrappers, beverage bottles and bottle caps, straws and stirrers.[7] Photos of animals entangled in ghost nets (remains of fishing gear floating in the sea) and stomach contents of seabirds, marine mammals and reptiles full of litter have helped raise public awareness. The impact of pollution on aesthetic values has joined with concern about the potential impact on human health by ingestion of microplastics through consumption of seafood. Similarly, alarm bells have been raised about the loss of mangrove forests due to the rise of aquaculture, the concretization of the inshore by rapidly expanding seashore cities and ports, and the spread of dead zones caused by the runoff of agricultural fertilizers. The ocean crisis has become increasingly visible. However, the long-term interaction of humans and the sea is still largely unknown and researching the history is beginning to reveal some deeper patterns beyond the obvious.

Pristine Waters?

One may like to think of the deep ocean as a pristine world that has never or only to a very limited degree been exposed to human activity. Yet today hardly any part of the ocean is wholly unaffected by humans, directly through extraction or indirectly through habitat change or biochemical impact.[8] Perhaps the only ecosystems in

[5] https://www.imo.org/en/About/Conventions/Pages/ListOfConventions.aspx, accessed January 7, 2021.

[6] *World Ocean Review 2010*, https://worldoceanreview.com/en/wor-1/pollution/over-fertilization/, accessed January 7, 2021.

[7] CBD—Secretariat of the Convention on Biological Diversity (2016). *Marine Debris: Understanding, Preventing and Mitigating the Significant Adverse Impacts on Marine and Coastal Biodiversity*, Montreal, Technical Series No. 83. S. Werner, A. Budziak, J. van Franeker, F. Galgani, G. Hanke, T. Maes, et al., (2016). *Harm caused by Marine Litter*. European Commission. JRC Technical Report.

[8] E. Ramirez-Llodra, P.A. Tyler, M.C. Baker, O.A. Bergstad, M.R. Clark, E. Escobar, et al. "Man and the Last Great Wilderness: Human Impact on the Deep Sea," *PLoS ONE* 6, no. 8 (2011): e22588. https://doi.org/10.1371/journal.pone.0022588.

the world totally unaffected by human activity are the geothermal worlds in the middle of the oceans where chimneys of hot underground gasses create an animal kingdom based on sulfur instead of sunlight. Even in the vast stretches of the deep sea at depths of more than four kilometers the impact of humans may be felt as contamination of debris or pollutants. However, the most important factor of life in the deep seas is the deprivation of energy caused by fisheries in upper water columns. Light does not penetrate to the lower levels of the ocean and therefore life depends on the carcasses of dead animals from above which provide food for the scavengers below—and the predators that prey on the scavengers themselves. A single dead whale sinking to the bottom of the sea will provide an abundance of food for deep-water animals.[9] Whale falls also work as carbon sinks of atmospheric greenhouse gas.[10] Historical whale hunting which reduced the largest of animals to a fraction of former population sizes will therefore have been and remains of major indirect effect on deep-sea life.

Human impacts are the most direct in the upper 500 meters of the water column as commercial fishing is not conducted in deeper waters. Indeed, geological extraction and construction of ports and windmill farms are typically conducted in waters of 50 m depth or less. In shallow and nearshore waters human impacts are palpable, even in remote parts of the world. Animal life in Antarctic waters is abundant and has been protected from commercial use for decades, yet hunting in the early part of the twentieth century changed the ecosystem to a degree that it can no longer be considered a pristine ecosystem. This is not to say that there are not pristine-like nearshore waters left on Earth. A case may be made for the northwest Hawaii islands, which have never been inhabited by humans and only very rarely have experienced fishing expeditions. Such locations are few—in fact, probably less than 1% of the ocean surface is fully protected against fishing or other kinds of disturbing activities.

To know the abundance of life in the pristine ocean, we need to look to historical sources for information. Archival records were kept by voyagers and fishers to describe what they saw and largely what they killed, ate, or used for other purposes. Yet we may glean something about what the oceans used to look like from accounts of the first encounters. In the eighteenth century, William Burke commented on the richness of the waters around Newfoundland:

> The plenty of cod, both on the great bank and the lesser ones which lie to the East and South East of this island, is inconceivable; and not only cod, but several other species of fish are there in abundance; all these species are nearly in an equal

[9] C.R. Smith and A.J. Baco, "Ecology of Whale Falls on the Deep Sea Floor," *Oceanography and Marine Biology, An Annual Review* 41 (2003), 311–354.

[10] A.J. Pershing, L.B. Christensen, N.R. Record, G.D. Sherwood, and P.B. Stetson, "The Impact of Whaling on the Ocean Carbon Cycle: Why Bigger Was Better," *PLOS ONE* 5, no. 8 (2010): e12444. https://doi.org/10.1371/journal.pone.0012444

> plenty all along the shores of New England, Nova Scotia, and the isle of Cape Breton; and consequently excellent fisheries are carried on upon all their coasts. Where our American colonies are so ill peopled, or so barren as not to produce any thing from their soil, their coasts make us ample amends; and pour in upon us a wealth of another kind, and no way inferior to the former, from their fisheries.[11]

A review of the diaries of some of the seventeenth- and eighteenth-century travelers who visited the Gulf of California, the enclosed sea between the desert peninsula of Baja California and mainland north-west Mexico, found that voyagers were struck by the diversity and abundance of the sea.[12] Failure to establish permanent human settlements on the barren coastlands turned the Gulf into a safe haven for pirates and buccaneers, some of whom wrote extensive accounts of their adventures including descriptions of the natural world. Late eighteenth-century missionaries were similarly struck by the natural richness of the Gulf. Common to all these travelers was that they saw infinite numbers of whales, "impossible to be counted." One captain noted three large pods of "above 500 whales" that followed his ship for about an hour "which were so huge, as it was wonderful." In 1798 whaling captain James Colnett wrote that sea lions occurred in hundreds of thousands, green turtles and hawksbill turtles "swarmed around" and "covered the sea." Similarly, the abundance of fish seems almost incredible by today's standards. The large grey Gulf grouper (*Mycteroperca jordani*) could be caught by hand and could quickly fill up all empty room in a ship looking for provisions. Reef fish such as the Goliath Grouper (*Epinephelus itajara*), which is very rare today, were frequently caught at weights of 150–250 kg. Tuna were abundant and sometimes chased sardines to the shore to pile up in hundreds of kilograms. Giant manta rays more than four meters wide and needing 15 men to pull them out of the water were frequently mentioned, while shark seemed less common than they were to become in the nineteenth century when other large animals had been hunted out of the ecosystem. What attracted the attention of the first commercial entrepreneurs was, however, the vast stretches, sometimes 500 km long, of pearl oyster beds. The pearl oysters had been collected by indigenous Indian populations for hundreds of years but the Europeans scaled up the effort. The fishery removed an estimated 2,500 million oysters before the industry collapsed in 1939. Today the oyster is very rare and while all the marine mammals and fishes may still occur, they are all deemed to be rare or very rare and appear in much smaller individual sizes today. Thus, a near-pristine sea was hunted and fished to depletion in less than 200 years, and most of the extractions took place by the nineteenth and early twentieth

[11] William Burke, *An Account of the European Settlements in America: In Six Parts*….II, London, printed for R. and J. Dodsley, 1757, 274.

[12] A. Sáenz-Arroyo, C. Roberts, J. Torre, M. Cariño-Olvera, and J. Hawkins, "The Value of Evidence About Past Abundance—Marine Fauna of the Gulf of California through the Eyes of 16th to 19th Century Travellers," *Fish and Fisheries* 7, no. 2 (2006): 128–146.

centuries, long before ecological concerns began to make an impact on fisheries management. By the time ecological concerns were raised, the memory of past abundance had already disappeared, and only the historical records make us aware of the world that was lost in the Gulf of California.

After a decade-long global survey, the Census of Marine Life concluded in 2010 that the abundance and distribution of oceanic life have been much reduced not least by habitat change in inshore waters ranging from harbor constructions to destruction of mangrove forests as result of aquaculture. As a rule of thumb, human extractions have reduced the abundance of large marine life by nine-tenths in the last 100 years. However, few marine species have been driven to extinction, and the evidence suggests that most populations may regenerate if appropriate conservation measures are introduced.[13]

Cornucopia

The seas may have been teeming with life but for early humans the sea had no attraction—or so it would seem based on current archaeological knowledge. However, the rise of sea levels after the last glaciation will have covered most traces of human activity below 20–100 meters of water, and the study of early human life may await exciting discoveries below water. The earliest positive remains of *Homo sapiens* shell fishing activity are dated 165,000 years ago and come out of Pinnacle Point, a cave overlooking the Indian Ocean on the South African coast. Today the cave is 15 m above mean sea level and thus escaped later sea rise. The people living here used red ochre for body paint, had stone blade tools, and ate at least 15 different species of invertebrates, predominantly brown mussel (*Perna Perna)*, giant periwinkle (*Turbo sarmaticus*), limpets (*Scutellastra argenvillei*) and whelks (*Buccinidae*). They would have easily collected these during low tide from the rocky shore and tidal pools below their shelter.[14] What drove these humans to subsist at least part of the year on such meagre foods? Possibly they may have used marine food to get through periods of scarcity. At the time the southern part of Africa was much drier than today and may have experienced periods of depressed food availability. Marine food would have provided a safety net for pockets of humans who had migrated out of northern inland Africa.

[13] Poul Holm, Anne H. Marboe, Bo Poulsen, and Brian R. MacKenzie. "Marine Animal Populations. A New Look Back in Time," *Life in the World's Oceans: Diversity, Distribution, and Abundance*, ed. A.D. MacIntyre, 3–23 (Oxford: Blackwell, 2010). H.K. Lotze, M. Coll, A.M. Magera, C. Ward-Paige, and L. Airoldi. "Recovery of Marine Animal Populations and Ecosystems," *Trends Ecol Evol* 26, no. 11 (Nov 2011): 595–605.

[14] C.W.Marean, M. Bar-Matthews, J. Bernatchez, E. Fisher, P. Goldberg, A.I. Herries, et al., "Early Human Use of Marine Resources and Pigment in South Africa During the Middle Pleistocene," *Nature* 449, no. 7164 (Oct 18 2007): 905–908.

Being able to subsist on the coastal shore made it possible to move along the coast, easier than through the dense inland. The spread of humans around the globe depended critically on the ability to find food in unknown territory and fishing opened a vast new resource to humans. Around 80,000 years ago there is ample documentation for regular captures by unknown means of large catfish (*Clarias*) from Rift Valley rivers.[15] By 45,000–65,000 years ago humans had spread into Asia, Europe, and Australia, and for that last leg of the journey would have needed floating vessels of some form. The ability to reach deeper waters made harpoons efficient tools for catching larger fish and mammals, and there is direct evidence in the skeletons of Middle Paleolithic human skeletons of a diet consisting in some instances of marine food. In the Later Upper Paleolithic from around 28,000 years ago, humans seem to have increasingly diversified their sources of food, including smaller game such as fish and birds and tortoise.[16] There is evidence of rays or skates being consumed on the Northern Coast of Spain some 30,000 years ago and of widespread consumption of salmon and other riverine fish.[17]

Three human skeletons dating around 10,000 BC from Kendrick's Cave in North Wales, UK, provide evidence of consistent intensive consumption of marine foods. Isotopic measurements of their bone collagen indicate that they got about 30% of their protein from mammals and large fish. Analysis of inland human skeletons showed no evidence for marine consumption so by the end of the Ice Age evidently different resource strategies had developed depending on proximity to the coast.[18] A similar high dependence on marine consumption has been proven around 9,500–11,500 BC on the Pacific Northwest Coast of America, roughly contemporary with strictly terrestrial inland cultures.[19]

The Holocene warm period which ended the last Ice Age about 10,000 BC saw a rise in temperatures in a few thousand years which changed landscapes and presumably the oceans profoundly. Warming seas changed the distribution of marine life, and the northern hemisphere which was the predominant sphere of human activity saw a rapid intensification of hunting and fishing. The warm period 8,000–5,000 BC with temperatures 2–2.5 C above today may be called the "fishing stone age" because of the well-developed fisheries technology and

[15] S. McBrearty, and A.S. Brooks, "The Revolution That Wasn't: A New Interpretation of the Origin of Modern Human Behavior," *J Hum Evol* 39, no. 5 (Nov 2000): 453–563.

[16] M.P. Richards, R. Jacobi, J. Cook, P.B. Pettitt, and C.B. Stringer, "Isotope Evidence for the Intensive Use of Marine Foods by Late Upper Palaeolithic Humans," *J Hum Evol* 49, no. 3 (Sep 2005): 390–394. Ruth Blasco, "Human Consumption of Tortoises at Level Iv of Bolomor Cave (Valencia, Spain)," *Journal of Archaeological Science* 35, no. 10 (2008): 2839–2848.

[17] Gema E. Adán, Diego Álvarez-Lao, Pablo Turrero, Miguel Arbizu, and Eva García-Vázquez, "Fish as Diet Resource in North Spain During the Upper Paleolithic," *Journal of Archaeological Science* 36, no. 3 (2009): 895–899.

[18] Richards et al., "Isotope Evidence for the Intensive Use of Marine Foods."

[19] Jon M. Erlandson, "Racing a Rising Tide: Global Warming, Rising Seas, and the Erosion of Human History," *The Journal of Island and Coastal Archaeology* 3, no. 2 (2008): 167–169.

strong dependence on marine foods. People living on the North Atlantic coast of Newfoundland and the Pacific coast of British Columbia, Canada, had diets that depended to an extreme degree on the rich seal populations which must have lived by the shore, while people living by the southern Californian coast similarly had a predominantly marine diet consisting of a broader selection of fish and mammals.[20] Overall, the Mesolithic period reached an all-time high of marine consumption per human capita which is today perhaps only matched by the most extremely marine-dependent populations of the globe such as the North Greenland Uummanaq people, many of whom will eat seal every day.[21]

The biodiversity of the North Sea and Baltic was much more varied 8000 years ago than it is today. The fishers mainly subsisted on gadoids (primarily cod), flatfish (plaice/flounder/dab) and eel but the traps that were likely their most important fishing gear were unselective, and the menu of the Mesolithic people was as diverse. The kitchen-middens or trash-heaps of fishbone and shells, which reveal what they consumed, show fish belonging to warmer or sub-tropical waters than the temperate seas today. The coast also had Dalmatian pelican (Pelecanus crispus), European pond turtle (Emys orbicularis) and Aesculapian snake (Elaphe longissima) which today are found in SE Europe. It is not surprising to find warm-water species at a time when the sea was considerably warmer than today. On the other hand, the presence of cod as a common species, both in the Mesolithic and today, is surprising. Their ancient presence would suggest that this species is resilient to long-term climate change if temperatures rise over an extended period.[22] This observation may be a cautionary tale against simplistic notions about the impact of future climate change.

Natural Variability

The pristine ocean was not static. One of the most dramatic advances in our understanding of the past is derived from the counting of fish scales deposited on the seabed. Normally fish scales will decompose quickly but in rare circumstances anoxic conditions in deep waters will preserve the fish scales through centuries and millennia. Such conditions prevail along the California Current from Baja California in Mexico to the Salish Sea in Canada. The method of counting fish

[20] M.P. Richards and R.E.M. Hedges, "Stable Isotope Evidence for Similarities in the Types of Marine Foods Used by Late Mesolithic Humans at Sites Along the Atlantic Coast of Europe," *Journal of Archaeological Science* 26 (1999): 717–722.

[21] Bjørn Buchardt, Vibeke Bunch, and Pekka Helin, "Fingernails and Diet: Stable Isotope Signatures of a Marine Hunting Community from Modern Uummannaq, North Greenland," *Chemical Geology* 244, no. 1–2 (2007): 316–329.

[22] Inge B. Enghoff, Brian R. MacKenzie, and Einar Eg Nielsen, "The Danish Fish Fauna During the Warm Atlantic Period (Ca. 7000–3900bc): Forerunner of Future Changes?" *Fisheries Research* 87, no. 2–3 (2007): 167–180.

scales in sediment core samples was developed in the 1960s[23] and has since been replicated to build up a series of studies that reconstruct the natural variability of a few pelagic species which have large and distinct scales.[24] A group of researchers under the direction of Professor Robert C Francis used the method to show dramatic oscillations in the occurrence of mackerel, sardine, and hake off the coast of California. They identified the major driving force over a period of 1600 years to have been climatic variability as caused by the Pacific El Niño—Southern Oscillation, while the human impact was felt only in the twentieth century as a contributory cause of the demise of the California pelagic fishery.[25] Francis was able to match the information of presence or absence of Pacific sardine in the reports of early explorers and naturalists with the evidence of core samples. In 1778 James Cook saw large quantities of "sardines—or a small fish very much like them" caught by native fishermen while visiting naturalists soon described the native fisheries for sardines along the Pacific Northwest coast. By the beginning of the nineteenth century, however, the evidence of core samples indicate that sardines declined in abundance and they were no longer being noted by European explorers and traders. In 1884 extensive scientific investigations failed to locate sardines in Pacific Northwest waters. Five years later, however, warmer climate again allowed sardines to range north to Puget Sound, by which time a large-scale commercial fishery began which lasted until 1948–49 when stocks once again disappeared. It is striking that human dependence on the riches of the ocean in the Pacific Northwest depended on climatic variability which only occasionally brought shoals northerly enough and close enough to the shoreline to allow fisheries to be undertaken. Such dependence on climate remains fundamental to fisheries today and has determined fishermen's luck everywhere on the globe. The pristine seas were as capricious as they were rich.

The role of natural variability for human life and the difficulties of societal responses is strikingly proven by the Peruvian anchoveta fishery which developed in the 1950s. Demand for cheap protein for agricultural use, mainly in the rearing of pigs and chicken, was a driving force behind the new large-scale pelagic trawling operations. Industrial reduction of low-value fish for meal and oil was a well-known technology, but it only took on large-scale proportions with the discovery of immense pelagic resources off the South American coast. Production

[23] Andrew Soutar and John D. Isaacs, "Abundance of Pelagic Fish During the 19th and 20th Centuries as Recorded in Anaerobic Sediment Off the Calfornias," *Fishery Bulletin* 72, no. 2, 1974 (1974): 257–273.

[24] T.R. Baumgartner, A. Soutar, and V. Ferreira-Bartrina, "Reconstruction of the History of Pacific Sardine and Northern Anchovy Populations over the Past Two Millennia from Sediments of the Santa Barbara Basin," *California Cooperative Fishery Investigations Reports* XXXIII (1992): 24–40.

[25] R.C. Francis, J. Field, D. Holmgren, and A. Strom, "Historical Approaches to the Northern California Current Ecosystem," in *The Exploited Seas: New Directions for Marine Environmental History*, edited by Poul Holm, Tim D. Smith, and David J. Starkey. Research in Maritime History No. 21 (St. John's, Newfoundland: International Maritime Economic History Association, 2002), 123–139.

went from 59,000 tons in 1955 to 3 million tons in 1960 and peaked in 1970 with 13.1 million tons, making it the world's largest fishery. Three years later the fishery collapsed with only 1.7 million tons landed as the combined result of overfishing and the recurrent climatic change known as the El Niño.[26]

The global climate and its effects on the aquatic environment are only poorly understood and large-scale ocean monitoring by satellite and arrays of sensors in the oceans has only begun in the last 10–15 years. Satellite observation has shown that the production of phytoplankton, which is the basis of almost all ocean food webs, varies on the decadal scale because of solar activity, water currents and upwelling systems. Warm temperatures will tend to separate warm and cold currents in the tropics and thus limit the growth of phytoplankton. Observed changes over the last 50 years, based on ocean sampling, indicate that phytoplankton growth has slowed, perhaps because of warmer ocean temperatures.[27] If indeed this coupling holds true it follows that oceans will have been more productive during the colder temperatures of the seventeenth to nineteenth centuries. Very long-term changes in phytoplankton abundance would provide shifting levels of basic foodstuffs for ocean marine life and thus changing animal abundance through the marine food web.

Acceleration

Market demand accelerated artisanal nearshore operations into large-scale oceanic hunts and fisheries. Archaeologists have identified a Northwest European "fish event horizon," *c*. 1000 CE, defined by a distinct change from freshwater to marine food from increasingly deeper waters.[28] The development of sea-going vessels led to a rise of fisheries in the upper 200 meter water column. Documentary evidence has recently been used to posit a dramatic step-change into a North Atlantic "fish revolution" after 1500, delivering large cod supplies to the European market.[29]

[26] Michael H. Glantz, "Man, State, and Fisheries: An Inquiry into Some Societal Constraints that Affect Fisheries Management," *Ocean Development and International Law* 17: 191–270. See also Andrew J. Pershing, Nicholas R. Record, Bradley S. Franklin, Brian T. Kennedy, Loren McClenachan, Katherine E. Mills, et al., "Challenges to Natural and Human Communities from Surprising Ocean Temperatures," *Proceedings of the National Academy of Sciences* 116, no. 37 (2019): 18378–18383.

[27] D.G. Boyce, M.R. Lewis, and B. Worm, "Global Phytoplankton Decline over the Past Century," *Nature* 466, no. 7306 (Jul 29 2010): 591–596.

[28] J.H. Barrett, A.M. Locker, and C.M. Roberts, "'Dark Age Economics' revisited: The English Fish Bone Evidence AD 600–1600," *Antiquity* 78 (2004): 618–636. D.C. Orton, J. Morris, A. Locker, and J.H. Barrett, "Fish for the city: meta-analysis of archaeological cod remains and the growth of London's northern trade," *Antiquity* 88, no. 340 (2014): 516–530. J.H. Barrett, "An environmental (pre)history of European fishing: Past and future archaeological contributions to sustainable fisheries," *Journal of Fish Biology* (2019): 1–12.

[29] P. Holm, F. Ludlow, C. Scherer, C. Travis, B. Allaire, C. Brito, et al., "The North Atlantic Fish Revolution (ca AD 1500)," *Quaternary Research* (2019). https://doi.org/10.1017/ qua.2018.153: 15.

Whaling was one of the most profitable extractive industries ever undertaken, and it was likely the one activity that impacted life in the oceans more than any other single pre-industrial endeavor. The hunts are well documented and researched. Yet we still do not know how many whales there used to be in the ocean and where. Despite some remarkable recent recoveries of certain species, such as the Northeast Pacific Gray Whale (*Eschrichtius robustus*), total marine mammal populations have declined since 1950 by about 56% in terms of total weight and by 11% in terms of numbers.[30] A global overview of the history of whaling identified 120 whaling operations grouped into 14 methodology-defined eras.[31] Maps of the spatial and temporal extent of whaling in the nineteenth century reveal areas where populations today have and have not recovered to their pre-whaling distribution. The catch history of North Atlantic Humpback (*Megaptera novaeangliae*) whaling was used in an International Whaling Commission sponsored stock assessment to estimate that current abundance is 37% to 70% of the historical abundance, which itself was 22,000–26,000. Another study of the historical distribution and landings of southern right whales (*Eubalaena australis*) was based on an analysis of over 150 whaling logbooks and other landings records. With 95% statistical confidence, population modeling shows that southern right whales numbered between 22,000 and 32,000 in the early 1800s, declining rapidly once whaling began. By 1925, perhaps as few as 25 reproductive females survived. Today the population has recovered to some 1,000 animals around sub-Antarctic islands south of New Zealand.[32] Genetic analysis of the diversity of current populations and DNA mutation rates indicates that the pre-contact population size of the Eastern Pacific Gray Whale (*Eschrichtius robustus*) was three to five times larger than the population size calculated by historical data.[33]

The largest fishery sustained through successive centuries began in 1497 when John Cabot returned to Bristol from a voyage across the North Atlantic. He told of waters so thick with cod that they could be lifted straight on board in baskets. Within a few years of this journey fishermen from all over Western Europe made the journey across to Newfoundland. Fish was a high-priced, limited resource in late medieval Europe. The Grand Banks fishery offered abundant high-quality low-priced catches. Using simple hook-and-line gear cod (*Gadus morhua*) catches amounted to more than 600,000 metric tons by 1788. It is likely that a collapse of

[30] Line Bang Christensen, *Marine Mammal Populations: Reconstructing Historical Abundances at the Global Scale* (Vancouver: Fisheries Centre, University of British Columbia, 2006).

[31] R. Reeves and T. Smith, "A Taxonomy of World Whaling," in J. Estes (ed.), *Whales, Whaling, and Ocean Ecosystems* (Berkeley, CA: University of California Press, 2007).

[32] Leigh Torres, Tim Smith, Phil Sutton, Alison MacDiarmid, and J.L. Bannister (2011), Habitat use and distribution patterns of southern right whales and sperm whales discerned from spatial analyses of 19th century whaling records. Prepared for Australian Marine Mammal Centre. Wellington, National Institute of Water & Atmospheric Research.

[33] S. Elizabeth Alter, Seth D. Newsome, and Stephen R. Palumbi, "Pre-Whaling Genetic Diversity and Population Ecology in Eastern Pacific Gray Whales: Insights from Ancient DNA and Stable Isotopes," *PLoS One* 7, no. 5 (2012): 1–12.

the fish stock was only avoided by the Napoleonic Wars which brought the fishery to a standstill and gave the stock a chance to rebuild. Such is the nature of human-ocean interaction that warfare on land often gives respite to marine life. After 1815 when fisheries resumed in earnest, stocks were still showing signs of depletion and expansion of the fishery was only possible through a geographical extension of fishing grounds into the sea, and from the 1830s along the Labrador coast.[34] Serial depletion or fishing down of one fishing ground to the next is a recognizable phenomenon through the history of the fisheries and has often concealed to the public mind the loss of marine life.

Major changes in world fisheries occurred after about 1880. The fresh fish industry profited greatly from the transport revolution of railways and steamships as easy transport changed the market profoundly. Fresh fish could be sent inland by train and arrive at markets that developed a taste for high-quality, high-value fish. Iced fish was transported in bulk and marketed to the urban population as cheap, low-quality, but nutritious food. The trawling industry concentrated on a narrow product segment (the whitefish industry) and soon faced a need to explore new fishing grounds. By the 1890s, the North Sea was showing signs of depletion and the fleet sought new grounds off the Faeroes and Iceland and later in the Barents Sea, which was regularly visited after the First World War. Many workers' homes had no kitchen or fireplace, and by 1920 some 20,000 fish-and-chips shops provided the urban masses with cheap food.[35]

High-seas fisheries were not only an economic option but widely perceived as a marker of national political presence on the world scene. The biggest impact of the British steam-trawling model was in the Pacific where the Japanese developed a deep-sea salmon fishery to feed a growing domestic market. A massive investment program brought Japan's landings on a par with the British already in 1910, and by 1938 Japan was the world's leading fishing nation with a catch of three million tons or three times the stagnant British landings.

Exhaustion

Global extractions expanded rapidly in the 1920s and 1930s from an estimated 9 million metric tons in 1914 to about 20.7 tons in 1938. The Second World

[34] John Nicholls, Bernard Allaire, and Poul Holm, "The Capacity Trend Method: A New Approach for Enumerating the Newfoundland Cod Fisheries (1675–1790)," *Historical Methods*, 2021, 1–14. Ransom A. Myers, "Testing Ecological Models: The Influence of Catch Rates on Settlement of Fishermen in Newfoundland, 1710–1833," *The Exploited Seas: New Directions for Marine Environmental History*, ed. by Poul Holm, Tim D. Smith, and David J. Starkey. Research in Maritime History No. 21 (St. John's, Newfoundland: International Maritime Economic History Association, 2002), 13–29.

[35] Robb Robinson, *Trawling: The Rise and Fall of the British Trawl Fishery* (Exeter: University of Exeter Press, 1998); John K. Walton, *Fish and Chips, and the British Working Class, 1870–1940* (Leicester: Leicester University Press, 1994).

War brought a temporary reprieve for ocean life and allowed commercial stocks of cod, haddock, and plaice to replenish after heavy fishing pressures during the interwar period. By 1950, global landings were back to the pre-war maximum, and the following decade saw landings rise quickly. Technology developed for naval warfare was turned into fish finding and navigational tools and changed hunting practices from trial and error to scientifically aided mapping. Sonar developed from the wartime asdic system detected shoals of fish beneath the surface and improved productivity immensely while Decca enabled the precise location of fishing banks.[36]

By the 1950s, catches in the Pacific soon became more important than the North Atlantic. Japan and the Soviet Union developed distant-water fisheries predicated on bulk. Soviet economists argued that it took fewer man-hours to capture one unit of fish protein than to produce one unit of meat. Huge investment plans went into creating fleets of huge trawlers over 1,000 Gross Register Tons serviced by hundreds of floating factories making 6–18 month trips up to 8,000 miles from home. High operation costs meant that none of the distant-water fisheries was profitable as such and required significant government subsidies. This was true of the Soviet as well as of the British and Japanese fleets.[37]

Landings of distant-water operations declined after 1980 thanks to the breakdown of the Soviet and East European fleets and the dissolution of the Japanese and British fleets. However, some developing countries opted to sell rights to fish to distant fleets rather than develop fleets of their own. Thus, West European fishing capacity was redistributed but largely maintained. Distant-water fisheries became increasingly controversial as fish-for-arms deals propped up some corrupt regimes. Illegal, Unreported and Unregulated (IUU) fisheries developed both inside poorly policed national waters and in international high seas, targeting also endangered species such as Atlantic Bluefin Tuna (*Thunnus thynnus*), Orange Roughy (*Hoplostethus atlanticus*) and Patagonian Toothfish (*Dissostichus eleginoides*). Today, as much as one-third of IUU fisheries are conducted in poorly managed Southeast Asian waters.[38]

By 1990, the known marine resources of the world were used to the full, and many fish stocks were indeed overexploited. World fish catches had increased fivefold from 17 million metric tons in 1950 to 91 million tons in 1995, but have since stagnated and indeed declined. Traditional capture fishing in the ocean was simply no longer able to yield more.

[36] Poul Holm, "World War II and the 'Great Acceleration' of North Atlantic Fisheries," *Global Environmental Change* (2013): 66–91.

[37] Poul Holm, "The Global Fish Market: Internationalization, 1880–1997," *Research in Maritime History* 13 (1998): 239–258.

[38] Joseph Christensen, "Illegal, Unreported and Unregulated Fishing in Historical Perspective," *Perspectives on Oceans Past*, edited by K. Schwerdtner Manez and Bo Poulsen (New York: Springer, 2016), 133–154.

Mariculture

As the potential of wild capture was exhausted, the culture of marine products, mariculture, presented a different pathway to harvesting ocean resources. While agriculture has a global history of at least 10,000 years, the history of mariculture is with few exceptions only decades long. The domestication of fish has been slow compared with terrestrial animals and remains restricted to a few species.[39] While freshwater aquaculture has a history that goes back millennia, mariculture only really developed in the last half of the twentieth century.[40]

It is tempting to see the growth of mariculture as replicating the Neolithic transition on land from hunting and gathering to agriculture. However, as Table 14.1 shows, most of the human consumption from the ocean still derives from capture fisheries. Most mariculture products come from low trophic levels such as algae, seaweed, and crustaceans. The most spectacular successes of mariculture have been salmon and crustacean production which developed in the 1980s and 1990s at considerable ecological cost. Shrimp farms were responsible for the destruction of large stretches of mangrove forests in tropical waters while salmon farms developed with the use of antibiotics and contamination of inshore waters. Rapid scientific progress and stricter management have mitigated many of these problems.[41] Future development of mariculture will depend on shifting human consumption from higher trophic levels such as finfish to lower levels such as plants and crustaceans.

Table 14.1 Human harvests from the oceans, 2015 (metric tons)

Marine production 2015	Capture	Culture
Crustaceans	6,063,118	4,494,725
Aquatic invertebrates	559,067	387,456
Molluscs	7,105,975	16,187,570
Finfish	67,451,119	6,810,121
Aquatic plants	1,088,162	29,273,392
	82,267,442	57,153,264

Source: FAO.

[39] Teletchea Fabrice, "Fish Domestication: An Overview," in T. Fabrice (ed.), *Animal Domestication* (London: InTechOpen, 2019), 69–90.

[40] Poul Holm, Bela H. Buck, and Richard Langan, "Introduction: New Approaches to Sustainable Offshore Food Production and the Development of Offshore Platforms," *New Approaches to Sustainable Offshore Food Production and the Development of Offshore Platforms*, ed. Bela Buck and Richard Langan (New York: Springer, 2017), 1–20.

[41] Science Advice for Policy by European Academies, *Food from the Oceans*. Luxembourg (European Commission) 2017.

Unsustainability

Two opposing concepts play a critical role in modern thinking about human impact on marine life. One is the idea of the "light touch," the other is the "tragedy of the commons." The light touch concept assumes that pre-mechanized hunting and fishing will have been of negligible impact on the abundance of marine life. However, historical and archaeological case studies reveal the surprising impact of early human predation on the size, distribution, or population structure of aquatic species from shellfish to sea mammals.[42] Simple practices such as hook-and-line fishery and harpooning might cause a significant reduction in animal abundance. What in one context was a sustainable fishery might be wholly detrimental in another. The crucial factor was the intensity of fishing. A few hundred hooks may take out fishes that will be quickly replenished by natural production while thousands of hooks in the waters may render unsustainable harvests. A key determinant is therefore human demography and consumption practices that may or may not prove ecologically viable. Examples of simple hunting practices that have decimated animal populations are legion and may be found around the planet through human history.

A telling example is in the short history of human exploitation of the ecology of New Zealand. The Maori were experienced sailors and hunters, and on their arrival around 1250 CE encountered a rich pristine marine and terrestrial ecosystem. Much of the terrestrial ecosystem was heavily impacted already by 1500, and at the time of the advent of European settlers in 1790 the distribution and population sizes of seabirds, fur seals, and sea-lions had been utterly changed and the pressure on inshore fish populations was increasing.[43] Fur seals (*Arctocephalus forsteri*), for instance, had been extirpated from the North Island and only colonies at the southern tip of the South Island awaited the arrival of Europeans to be hunted almost to extinction. This final phase of the hunt did not come with much in terms of new technology, but it did come with the full force of market demand. A fashion for fur coats in China created the profits that made even the most remote seal populations vulnerable to human predation. Thanks only to preservation legislation in 1875 and 1878 did the fur seal population survive and live to rebuild.[44]

[42] Torben C. Rick and Jon Erlandson, "Human Impacts on Ancient Marine Ecosystems," in *Human Impacts on Ancient Marine Ecosystems: A Global Perspective*, edited by Torben C. Rick and Jon Erlandson, 1–19 (Berkeley, CA: University of California Press, 2008, p. 5).

[43] I.W.G. Smith, Estimating the Magnitude of Pre-European Maori Marine Harvest in Two New Zealand Study Areas. *New Zealand Aquatic Environment and Biodiversity Report* No. 82. Wellington: Ministry of Fisheries Wellington, 2011. A.B. MacDiarmid, E. Abraham, C.S. Baker, E. Carroll, C. Chagué-Goff, P. Cleaver, et al. *Taking Stock–the Changes to New Zealand Marine Ecosystems since First Human Settlement: Synthesis of Major Findings, and Policy and Management Implications*. New Zealand Aquatic Environment and Biodiversity Report 170 (2016).

[44] Colin M. Miskelly, "Legal Protection of New Zealand's Indigenous Aquatic Fauna—An Historical Review," *Tuhinga* 27 (2016): 81–115.

The concept of the "tragedy of the commons"[45] provides a counter-image of humanity's supposed ingrained individual pursuit of gain at the expense of the common good and has been much used to argue for the need to regulate the fisheries. The theory is that in a system of no controls the individual gain of killing the last animal will outweigh the long-term interests of all in conserving renewable resources. In essence, the theory argues that the Prisoner's Dilemma will tend to prioritize individual needs over communal gain. There is, however, evidence of sustainable extraction of marine life through centuries or even millennia in regions of sparse human population, and indeed of conservation practices in more heavily exploited regions. Strict regulations against blocking the passage of anadromous fishes by river weirs were enforced by Indigenous people in Pacific Northwest America.[46] Communal practices of restrictions on fishing days in Hawai'i and legislative measures, ranging from legislation to town regulations and inter-community agreements, to enforce the same in medieval Europe all point to an awareness of the need to allow resources to regenerate.[47]

Modern society similarly does not necessarily conform to a tragic model. A study of commons and community in three case studies of the Isle of Wight (UK), Connemara (Ireland) and the Dutch Wadden Sea stressed the importance of actor-networks in processes involving multiple stakeholders pursuing rational but conflicting choices.[48] Actors may overcome the dilemmas inherent in rational choice models by collective action, involving the development of trust and a sense of community. Actors did observe and tried to mitigate the consequences of their actions while negative attitudes to government intervention ruled out other actions.

In conclusion, archaeologists and historians have discarded concepts such as the "tragedy of the commons" as much as any a priori beliefs in the negligible impact of simple technology or the propensity of pre-modern societies for sustainability. The debunking of popular myths may be bad news for anyone seeking prescriptions for management based on ecological and sociological models, but historical analysis demonstrates the contingency of cultural and social communities. The long human history of hunting and fishing must be reviewed with a skeptical mind as regards claims of sustainable practices. As top predators, humans rarely have the perfect knowledge to conserve an ecosystem, much less so an ecosystem below water.

[45] Garrett Hardin, "The Tragedy of the Commons," *Science* 162: 3859, December 13, 1968.

[46] H.K. Lotze and Loren McClenachan, "Marine Historical Ecology Informing the Future by Learning from the Past. M. Bertness," in *Marine Community Ecology and Conservation*, edited by B. Silliman, J. Bruno, and J. Stachowicz (Sunderland, MA: Sinauer, 2013).

[47] Loren McClenachan and John N. Kittinger, "Multicentury Trends and the Sustainability of Coral Reef Fisheries in Hawai'i and Florida," *Fish and Fisheries* 14, no. 3 (2013): 239–255.

[48] N.A. Steins, *All Hands on Deck: An Interactive Perspective on Complex Common-Pool Resource Management Based on Case Studies in the Coastal Waters on the Isle of Wight (UK), Connemara (Ireland) and the Dutch Wadden Sea*. Wageningen University, 1999.

Legislation

In most cultures around the globe, the right to use marine resources was considered open to anyone, if for no other reason than the impracticality of denying entry. Access to the beach without which no boat could be launched was another thing. Roman law stipulated free passage to the beach for any fisher. In Northern Europe the legal situation was more conflicted. Farmers in the Baltic archipelago maintained their sole right to fish based on ownership of the land, while around the North Sea the foreshore tended to be under the protection of the Crown who would guarantee free access to all, regardless of nationality on the payment of tax. Global claims to the seas and lands beyond Europe were agreed by the kings of Spain and Portugal in the treaties of Tordesillas (1494) and Zaragoza (1529). These imperial claims were contested by the Dutch lawyer Hugo Grotius in 1609 in his treatise *Mare Liberum*. Grotius held that that the sea is an inexhaustible, common property and that all should have open access to it. Well into the twentieth century, the principle of Mare Liberum (The Free Sea) was maintained by major Western powers to argue their right to access and utilize waters around the globe up to a distance of a cannon shot or three nautical miles (5.5 kilometers) limit. By the late nineteenth century, concerns about overfishing of nearshore waters caused these legal principles to be turned into practical measures for managing fishing access. The Hague Convention of 1882 established exclusive fishing rights for national fishermen within the 3-mile boundary, whereas all other waters in Northern Europe were to remain open to anyone.

Management Advice

In 1883, at the First International Fisheries Exhibition in London, which attracted diplomats and scientists from all continents, Thomas Henry Huxley, a world-famous fisheries scientist, boldly claimed that "probably all the great fisheries are inexhaustible; that is to say that nothing we do seriously affects the number of fish."[49] Huxley's proclamation was soon countered by Ray Lankester, a professor of zoology, who struck a more conservative note: "the thousands of apparently superfluous young produced by fishes are not really superfluous, but have a perfectly definite place in the complex interactions of the living beings within their area."[50] These conflicting statements indicate two positions that continue to generate conflict over fisheries management to the present day. Despite the longevity of

[49] T.H.H. Huxley (1883), Opening address. Fisheries Exhibition, London (1883). http://math.clarku.edu/huxley/SM5/fish.html, accessed January 7, 2021.

[50] E.R. Lankester (1890), "The Scientific Results of the International Fisheries Exhibition, London 1883," in *The Advancement of Science. Occasional Essays and Addresses*, edited by E.R. Lankester (London, 193–223).

the argument, the fundamental issue was soon resolved. In 1900, Walter Garstang analyzed British scientific and commercial trawl data and concluded that "the rate at which sea fishes reproduce and grow is no longer sufficient to enable them to keep pace with the increasing rate of capture. In other words, the bottom fisheries are undergoing a process of exhaustion."[51]

Garstang's conclusion influenced the establishment in 1903 of the International Council for the Exploration of the Seas, namely the North Atlantic. ICES was based on the idea that all nations would benefit from some form of regulation of harmful fisheries.[52] Precautionary concerns were further boosted when scientists documented that depleted fish stocks had regenerated during the First World War. In fisheries science the war became known as the Great Fisheries Experiment. Fishers and scientists agreed that catches were bigger and better than before the War because of the four-year effective moratorium on fishing. The conclusion was inescapable: conservation measures work and may generate long-term benefits to the fishery that justify short-term losses.

Observation and modeling of fish stocks rapidly improved in the first half of the twentieth century. By the 1950s, the focus of fisheries scientists was to identify maximum sustainable yields (MSY). Ideally, MSY would enable fisheries to obtain the twin objectives of economic and ecological equilibrium: deriving the best economic results while not extracting more fish than the stocks would replenish.[53] Fisheries science developed into highly sophisticated scientific institutions equipped with research ships, laboratories, and advanced mathematical models. At the same time, however, models showed that fish stocks around the world were dwindling. It seemed that fisheries science only helped to closely observe the collapse of marine life. In academic institutions the division of labor and indeed sometimes tensions increased between pure science, the interest in biodiversity, food webs and biological processes and functions, and the applied dimensions, the extraction of natural resources for human use.[54]

Law of the Sea

While consensus on the need for fisheries management had been reached in principle after WWI, international implementation proved difficult, and in effect

[51] W. Garstang (1900), "The impoverishment of the sea: a critical summary of the experimental and statistical evidence bearing upon the alleged depletion of the trawling grounds," *Journal of the Marine Biological Association of the UK* 6, no. 1 (1900), 1–69; cf. Tim D. Smith, *Scaling Fisheries—The Science of Measuring the Effects of Fishing, 1855–1955*. Cambridge (1994): 106–108.

[52] H.M. Rozwadowski, *The Sea Knows No Boundaries. A Century of Marine Science under ICES* (Seattle, WA/London: University of Washington Press and ICES, 2002).

[53] Carmel Finley, *All the Fish in the Sea: Maximum Sustainable Yield and the Failure of Fisheries Management* (Chicago, IL: University of Chicago Press, 2011).

[54] T.D. Smith, *Scaling Fisheries*.

remained unresolved for decades. The International Conference on the North Sea Plaice Fisheries in 1925 did recognize in principle the value of closing zones of the sea to fishing but also considered it "impracticable" to get all nations to agree to such measures. Instead, the conference agreed that future focus should be on limiting the mesh sizes of trawls to reduce catches of undersized fish. Unfortunately, negotiations stalled and by the outbreak of WWII had made little real progress.

After the war scientists were conscious that stocks had replenished but might soon be fished out if no action was taken. In 1946, governments signed the North Sea Convention which finally introduced technical measures such as minimum mesh and fish sizes. However, the signatories agreed to an opt-out clause and to delay the implementation of the convention till 1954 which effectively rendered the convention meaningless. By then the North Sea stocks had already been fished down to pre-war levels. In 1948 unilateral action was taken by Norway to enforce a 4-mile exclusive fishing zone and prosecute a considerable number of British distant-water trawlers who were found inside this limit. The United Kingdom brought the case before the International Court of Justice which in 1951 ruled in favor of the Norwegian implementation of a system of straight baselines. The verdict was deemed to upset "much previous thought and practice … leaving the law in a somewhat fluid and imprecise state."[55] Following the verdict, Iceland moved quickly to introduce a similar measure against foreign, primarily British trawlers in Icelandic waters.

Ultimately, the game-changer to the management of the seas came in a declaration of national self-interest in the Pacific. On September 28, 1945, US President Truman issued two declarations against a potential future threat from Japan. In the future, the American government would safeguard its economic rights to natural resources on the continental shelf, including mining and fishing. The declaration acknowledged the right of any state to establish conservation zones off its shores.[56] The Truman Declarations had immediate and long-term consequences. In the short term, they informed the governments of Chile and Peru which had a long history of contested waters. In 1947 both countries claimed a 200-mile maritime zone. The conflict was only resolved in a verdict by the International Court of Justice in 2014 and was only the first of many disputes over the sovereignty of what came to be known as Exclusive Economic Zones or EEZs.[57]

In 1958, the fluidity of international law and increasing disputes over access to marine resources caused the United Nations to call an International Conference

[55] D.H.N. Johnson, "The Anglo-Norwegian Fisheries Case," *The International and Comparative Law Quarterly* 1, no. 2 (1952), 145–180.

[56] http://www.ibiblio.org/pha/policy/1945/450928a.html, accessed February 15, 2013.

[57] D. Anton, "The Maritime Dispute between Peru and Chile," *E-International Relations*, 2014. https://www.e-ir.info/2014/03/18/the-maritime-dispute-between-peru-and-chile/, accessed January 7, 2021. S. N. Nandan, The Exclusive Economic Zone: A Historical Perspective. https://www.fao.org/3/s5280t/s5280t0p.htm [accessed 20 Oct 2021].

on the Law of the Sea, which was to be the first of three. The Conference agreed to extend territorial limits to 12 nautical miles, but this proved a short-lived solution. The inshore waters of coastal states, both in the developed and developing world, were under increasing pressure by distant-water fleets of stern trawlers with ever-increasing fishing power. The conflict crystallized in decades of so-called cod wars between Iceland and the UK, which only ended in 1976 when both parties accepted a 200-mile Exclusive Economic Zone around Iceland. The principle of EEZs was finally made into the United Nations Convention on the Law of the Sea in 1982. Paradoxically, the United States which had initiated the legal process by the Truman declarations did not join the declaration although it recognizes it in practice.

Implementation and Enforcement

Management of life below water depends not only on science and laws but on implementation and enforcement. Satellite monitoring and computerized reporting are improving but fisheries management in most countries mainly takes place in port when fish is being landed. Illegal, unreported and unregulated fishing is rampant, especially in the high seas but also inside the EEZs of many countries.[58] A report in 2017 estimated that improved management tools for a large number of overfished stocks and reduced discards by more selective fishing might increase the global annual catch of seafood by as much as 30 million tons per year. An additional gain of a further 30 MT might be obtained by utilizing wastes associated with discards and processing. Such gains would, however, require reduced landings for several years to allow stocks to rebuild.[59]

Indirect subsidies, including protectionist measures, and loans and payment by government for distant water fishing licenses, distort fleet size and encourage wasteful fishing practices. In 1989, the United Nations Food and Agriculture Organization (FAO) estimated that total world revenues in fishing of around $70 billion were achieved at total operating costs of the world's fishing fleet of $92 billion; including capital costs, the deficit was calculated to be about $54 billion. An estimate in 2013 calculated that state subsidies were in the order of $35 billion but the figure is uncertain due to the lack of transparency of official data. Nation-states around the globe continue to subsidize overfishing, primarily by tax-exemptions for fuel and subsidies to build vessels.[60]

[58] Joseph Christensen, "Illegal, Unreported and Unregulated Fishing in Historical Perspective," in *Perspectives on Oceans Pas*, edited by K. Schwerdtner Manez and Bo Poulsen, 133–154 (Dordrecht: Springer, 2016).

[59] *Food from the Oceans*, 94.

[60] *Food from the Oceans*, 83.

The lack of integrated implementation of policies across policy sectors is another major constraint on the management of the sea. The health of life in inshore waters is impacted by run-offs from watersheds and coastal construction as much as by marine processes. The Earth Summit in Rio de Janeiro in 1992 incorporated integrated coastal zone management (ICZM) as a cross-cutting policy for coastal and inshore management concerns and in 1993 the World Bank recommended best practices.[61] However, ICZM is implemented only to a limited degree in most countries as institutions and ministries often have siloed missions.

In recent years, conservationists have argued that the best way to protect marine habitats and build endangered species is by restricting human access to marine protected areas (MPA). Typical MPA candidates are coral reefs, fragile spawning areas, and hot spots of marine biodiversity. There has been a rapid growth of MPAs in the last decade and by 2021 2.7% of the oceans are in fully or highly protected areas.[62] However, critics point to the lack of policing and the designation of MPAs in areas that are of little economic and ecological interest.[63]

Human Ocean Legacies

As conservation policies have been developed, ocean managers are confronted with new problems the scale of which we are only beginning to grasp and both of which are caused by human action. Ships have carried alien species around the seas through the last millennium or more, but modern ballast water tanks have greatly exacerbated the problem. Each year, about 10 billion tons of ballast water are transferred around the globe, carrying thousands of alien species to new locations. Most perish but some arrive in a place with no natural competitors and in a few years may come to completely dominate the ecosystem. In the nineteenth century, the European periwinkle (Littorina littorea) displaced the American eastern mud snail (Nassarius obsoleta) which in turn displaced the Californian horn snail (Cerathida californica). Invasive species may have huge ecological and economic impacts and present threats to habitats and human wellbeing.[64] A review concluded that marine invasive species present a large field of scientific unknowns, ranging from the validation of data to pathways. The International Maritime Organisation agreed on an International Convention for the Control and Management of Ships' Ballast

[61] World Bank, *Guidelines for Integrated Coastal Zone Management* (Noordwijk, NL: World Coast Conference, 1993).

[62] *Marine Protection Atlas*, https://mpatlas.org/zones/, accessed January 7, 2021.

[63] Caitlin Kuempel, Kendall Jones, James Watson, and James Possingham, "Quantifying biases in marine-protected-area placement relative to abatable threats," *Conservation Biology* 33, no. 6 (2017): 1350–1359.

[64] *Marine Menace*: https://www.iucn.org/downloads/marine_menace_en_1.pdf, accessed January 7, 2021.

Water and Sediments which entered into force in 2017.[65] Ships are now required to carry a ballast water record book and will eventually need to install an on-board ballast water treatment system.

The single most alarming change in oceanic life is acidification, the ongoing decrease in pH as a result of the uptake of carbon dioxide from the atmosphere. Acidification decreases carbonate and makes coral and some plankton shells fragile and potentially begin to dissolve. Acidification could cause the collapse of some critical ecosystems. While the problem is caused by relatively recent carbon emission it will remain with us for centuries as the CO2 has already been released as a legacy of past fossil fuel economies.

Maritime Communities

Life below water is of direct and indispensable importance for life on Earth. Every second breath is of oxygen generated by oceanic phytoplankton. Fish provide direct income for some 50 million fishers around the globe. The health of marine ecosystems is of immediate importance for the nutrition, economy, or coastal protection of some 775 million people.[66] In other words, the livelihood of roughly 10% of the population of the planet depends directly on healthy marine ecosystems. Life below water is key to human life above water.[67]

Traditionally, humans have built strong communities to overcome the challenges of a hostile environment such as the marine. Communities are social networks, larger than the single boat-crews or fishing businesses, which provide group resilience in the face of environmental and market factors, and communities pass down skills through generations.[68] With the tremendous increase in fishing power over the last century thanks to mechanization and digitization of operations, the customary link between the home base of fishing operations and fishing grounds is breaking up. The selling and buying of fish quotas have established national and international markets of production capacity. In Western

[65] https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx [accessed 20 Oct 2021].

[66] https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Control-and-Management-of-Ships%27-Ballast-Water-and-Sediments-(BWM).aspx [accessed 20 Oct 2021].

[67] S. Jentoft, "Life above Water: Small-Scale Fisheries as a Human Experience," *Maritime Studies* 19, 389–397 (2020). https://doi.org/10.1007/s40152-020-00203-0. Maarten Bavinck, "The Featuring of Small-Scale Fishers in SDG 14: Life below but Also above Water," in Anna-Katharina Hornidge and Werner Ekau (eds.), *Transitioning to Sustainable Life below Water* (MDPI, 2021). https://res.mdpi.com/bookfiles/edition/1405/article/3050/The_Featuring_of_SmallScale_Fishers_in_SDG14_Life_below_but_Also_above_Water.pdf?v=1612700844, accessed February 14, 2021.

[68] Poul Holm, "Historical Fishing Communities," in *Perspectives on Oceans Past: A Handbook of Marine Environmental History*, edited by K. Schwerdtner Máñez and B. Poulsen, 31–46 (Springer, 2016).

countries concentration of ownership has dramatically impacted fishing communities in countries such as the UK, Iceland, and New Zealand. In Denmark, no less than 50 fishing ports closed in the last decade.[69]

The countries most dependent on marine resources are Indonesia, Philippines, Nigeria, Vietnam, and Myanmar.[70] Strong fishing communities are still very much in evidence in developing countries around the globe but are often leading precarious existences on the margin of societies and many with poor incomes. Poverty, food security, and overexploitation of marine resources often constitute a downward spiral. Sustainable management, developing markets for low-trophic level seafood, and restoring marine habitats are solutions to be found above water for life below water and are critical to overcome poverty and malnutrition.

Life below water may be a world that we do not see but on which our life depends. The oceans and seas are still subject to open access and unrestricted human practices in most regions of the world, and the underwater world remains the last frontier, still to a large degree unexplored by humans.[71]

[69] Emma Cardwell and Robert Gear, "Transferable Quotas, Efficiency and Crew Ownership in Whalsay, Shetland," *Marine Policy* 40 (2013): 160–166. J.E. Høst, *Captains of Finance: An Inquiry into Market-Based Fisheries Management*. PhD thesis, University of Copenhagen, 2012.

[70] Selig et al. (2019).

[71] More than 80% of the ocean realm is unmapped, unobserved, and unexplored, https://oceanservice.noaa.gov/facts/exploration.html, accessed January 7, 2021.