A COMPANION TO AMERICAN ENVIRONMENTAL HISTORY

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Chapter Twenty-three

Oceans: Fusing the History of Science and Technology with Environmental History

Helen M. Rozwadowski

Environmental historians have forged sophisticated understandings of interrelationships between humans and many parts of the natural world. The oceans – especially the great depths and the open seas – remain a challenge. In 1864, Henry David Thoreau expressed deeply held cultural assumptions about the timelessness and imperviousness of the sea:

> We do not associate the idea of antiquity with the ocean, nor wonder how it looked a thousand years ago, as we do of the land, for it was equally wild and unfathomable always. The Indians left no traces on its surface, but it is the same to the civilized man and the savage. The aspect of the shore only has changed. (1896: 85)

This apparent contrast between land and sea continues to hold sway; the ocean remains to many "empty of history, utterly without a past" (Stilgoe 1994: 30).

To the extent that historians have begun, recently, to turn seaward, the view seems always to include land as well as sea – islands, beaches, littoral environments, and ocean basins with an emphasis on rims. Scholars who take seriously the aims of environmental history must also seek to historicize the ocean itself, including its most remote parts, because even those are as intertwined with human history as the far corners of the terrestrial world. Similarly, histories of the ocean that deal only with oceanic peoples or those engaged in maritime work will never be as comprehensive as those that also succeed in accounting for the myriad other groups of people who interact with the ocean – consumers, writers, scientists, recreationalists, policymakers, dreamers – some of whom never even see the ocean. This essay situates

the oceans in environmental history by reviewing efforts from the range of fields that contribute to historicizing the ocean and by proposing a framework for writing histories of the ocean that can encompass even areas and aspects of the sea that seem remote from people.

The ocean seems fundamentally different from land. Simply adding the expansive territory of the world's salt waters to the terrestrial realms historians usually study might not be sufficient. People are closely intertwined with the oceans, but we do not live there. We do visit, work, fight, and play at and under the sea. We extract resources from and create cultural understandings of the sea. Yet the ocean is fundamentally opaque, indifferent to human presence, and often a hostile place for people – an environment perhaps more akin to outer space, the polar regions, or the cultural construct of "wilderness" than to places traditionally scrutinized by most historians. Environmental historians have probed and expounded upon wilderness but have hardly begun to take on environments such as space, the poles, or the deep ocean. To tell the history of the ocean, this essay argues, demands a new approach, one that builds on terrestrial environmental history but requires adaptations to account for the peculiarities of the ocean environment and human responses to it.

Among its noteworthy accomplishments, environmental history has become adept at using up-to-date science, especially ecological knowledge, to explicate the past. Possibly the most original contribution of the field is its insistence on taking seriously natural boundaries and ecological time in the face of historical units of both time and geography established by political, economic, and social factors. Something environmental history does less consistently – namely, investigating the knowledge systems, inherited and created, by which historical actors understood the natural world – may prove critical for the ocean, because of ways in which the sea differs from land.

In its inaccessibility, most of the ocean is a vast and challenging place that humans know only through the mediation of technology and knowledge systems. Fishermen have long known the ocean through their nets and ships – and also through the hard-won knowledge they passed down from generation to generation. Explorers likewise knew the ocean through sails and navigational instruments and techniques – and also through knowledge recorded in earlier government reports and expedition narratives. Different groups of coastal people have known, used, and explored the ocean to different degrees and for an array of reasons. Enlightenment natural philosophers, and later modern scientists, have known the ocean through tide gauges, sounding devices, and water samplers. People whose work does not take place on oceans can, nevertheless, come to know the sea, through maritime novels, passenger travel, and recreational activities on and in the water. Indeed, because of the mediated nature of knowledge about the ocean, cultural conceptions of this space are as central as technologies to the project of writing the history of the ocean.

Knowledge about the ocean has been employed in myriad ways, including to help people harvest resources, conduct trade, develop industries, dominate other people, migrate, demonstrate cultural achievement, and accomplish many other endeavors. Traditionally, such activities have themselves formed the subjects of historians' work. But the uses people have made of the ocean can also serve as a springboard for writing a history of the ocean. The scholarly literatures and the questions of two fields in particular – maritime history and the history of science and technology – will be integral to writing the history of the ocean. Taking a cue from Richard White (1995), knowledge about the ocean has been produced through work. Maritime history, then, can offer an avenue for exploring how labor at, on, and in the sea defined the human relationship with the ocean. Since at least the late eighteenth century, the practices of modern science have formed a critical dimension of this relationship. Knowledge systems of all cultures that have encountered or imagined the sea mediate uses and conceptions of the ocean, as do the technologies that enable human interactions with the sea. Looking beyond uses to knowledge formation provides insights into the motives, expectations, and actions of groups of people interacting with the ocean. The history of science, then, suggests that scientific work, along with maritime work, has in a sense been constitutive of the ocean environment itself.

Foundations for Ocean History

Very recently, the oceans have begun to attract scholarly attention across the disciplines, reflecting the growing concerns about depleted fisheries, ecosystem shifts in the sea, and the role of the world's oceans in the global climate. This new ocean focus is manifested far beyond the natural sciences and the realm of policymaking; the ocean is making an appearance in a broad spectrum of disciplines.

Geography, especially historical geography, has begun to contribute its sensitivity to space toward an understanding of how different cultures and different times perceived the sea (Steinberg 2001). Geography's focus on space and place provides a logical entry to academic study of the oceans and coastal areas. Disciplines such as history and political science often neglect the oceans, but geography has a built-in framework for studying and comprehending such spaces. In addition, the field now includes a group of scholars interested in coastal and marine geography (the Coastal and Marine specialty group of the American Association of Geographers) (Steinberg 1999; Psuty et al. 2004). Historians, including historians of science and environmental historians, have begun to look to geography when writing about vast terrestrial spaces and widely dispersed endeavors (Carter 1987; Livingstone 1995; Smith and Agar 1998). The application of the questions

and methods of geographers to histories of people and oceans will prove invaluable to studies of this vast, remote, and inaccessible environment.

Historical ecologists and fisheries scientists have forged an innovative partnership with historians to document past populations of marine organisms. The History of Marine Animal Populations (HMAP) project forms part of the global Census of Marine Life, a major international science program aimed at enumerating what did, does, and will live in the sea. To uncover past marine populations, modelers and ecologists recruited maritime historians to help identify and mine archival records to provide data or proxy information about past sizes of fish stocks and whale populations. In addition to contributing to scientific understanding of the oceans, HMAP has also sponsored gatherings aimed at contributing to environmental history (Holm et al. 2001). Recent scholarship has taken HMAP data and begun to consider it more firmly within the humanities tradition of history (Rosenberg 2005; Bolster 2006), though some historians believe this partnership has benefited science more than history (van Sittert 2005; Anderson 2006).

One additional limitation of the HMAP-inspired effort to create a field of "marine environmental history" lies in its resource-centered perspective. As the geographer Philip Steinberg (2001) points out, fish and oil and other resources are extracted from a very small proportion of the ocean's vast extent. A comprehensive history of the oceans must take into account the actual uses of all parts of the sea, including transportation, communication, and warfare, the ocean's paradoxical role as both bridge and moat, and also the simultaneous reality and imagining of the sea (Labaree 1975; Rozwadowski 2005).

Other fields have contributed, but could potentially contribute more, to writing the history of the ocean. The study of maritime literature is an established enterprise, one that not only provides insights into topics such as shipboard life, maritime cultures, and conceptions of the ocean, but also makes extensive use of historical sources and contributes to understanding the past (e.g., Bercaw Edwards and Heffernan 2004; Bercaw Edwards 2009). Recently, literary scholars have addressed the historicity of the ocean directly, mostly in the realm of cultural conception (Klein and Mackenthun 2004). Other fields can, and do, likewise contribute to our understanding of cultural constructions of the ocean and how those shape human use of and ideas about the sea, ocean spaces, and marine resources. Anthropology and sociology also can contribute to our understanding of cultural constructions of the ocean as well as island cultures, coastal communities, and cross-cultural contact in many oceans (Dening 1980, 1992, 2004; Finlayson 1994; Binkley 2002). Cultural history and landscape history also offer rich dividends for considering the ocean (Corbin 1994; Stilgoe 1994).

Only one branch of history, maritime history, pays attention to the watery three-quarters of the globe. Maritime history has always offered a venue, tightly connected to material culture and public history, through which

historians could focus on the sea. People who traversed the ocean or worked on ships earned the scrutiny of scholars interested in naval battles, the transatlantic trade, and the whaling industry (Labaree et al. 1998). Unfortunately, maritime history is not well integrated into general US history, with the distinct exception of colonial history. Few university history departments in the United States offer maritime history courses or hire specialists in that field. Though maritime history enjoys wide popular appeal, it trespasses sloppily over the national boundaries that ordinarily separate scholarly specialties.

The field, however, seems poised to integrate fresh approaches and questions from across the historical profession. Just a decade or two ago, maritime history partnered with social history to reveal, in a number of important studies, myriad ways in which the maritime world reflected and elucidated events and trends on land (Rediker 1987; Creighton 1995; Creighton and Norling 1996; Bolster 1997; Norling 2000; Rediker and Linebaugh 2000; Gilje 2004). Maritime history focuses on the work, society, and culture of the maritime world ashore and afloat. Ships and port towns are stages for action, but few maritime historians shift their gaze to the ocean itself, an omission noted by Daniel Vickers (1993). Yet the potential contribution of maritime history to marine environmental history is great, because this field offers an avenue for exploring how labor at, on, and in the sea defined the human relationship with the ocean.

What of other fields of history? Recently, some scholars have begun to view maritime history as an ideal lens for interpreting global history, because of the physical connection between places that the ocean offers (Finamore 2004). Ocean-basin views of maritime regions such as the Mediterranean, Pacific, or Atlantic provide historians with geographically defined, transnational ways of organizing history, starting with Braudel's (1972) famous study. A recent forum in the *American Historical Review* surveyed scholarship in this vein (Wigen 2006). Scholars are taking a cue from this work and exploring oceans – not only the Atlantic and the Mediterranean Sea, but also the Pacific and Indian Oceans – although not yet extending to the Arctic Ocean (McDougall 1993; Horden and Purcell 2000).

The Atlantic world has emerged as a strong focus of scholarship, encompassing the history of slavery, diaspora studies, imperialism and colonialism, and the relationships between nations and regions, in addition to traditional strengths in colonial British and American history, naval history, and maritime economic history (Bailyn 2005). The body of Atlantic world scholarship has richly illuminated the dividends of transnational approaches and inquiries that focus on exchanges and connections between places. While much of this work focuses on the land-sea interface and on people more than oceans, John Gillis's (2004) study of islands offers a compelling model for Atlantic world scholarship. Gillis explored the meanings and significance of Atlantic islands – both the real and the imagined – from ancient Greece and Rome through the twentieth century. At each point in

time it is possible to see reflected in the characterization of islands the contemporaneous cultural conception of the ocean.

One invaluable contribution of ocean-basin scholarship to a history of the oceans is its demonstration that historians must cross political and cultural boundaries to follow human actors across bodies of water. This work is, however, predicated on an understanding of the sea as a highway or stage. Kären Wigen, in her introduction to the *American Historical Review* forum "Oceans of History," reminds historians that, "the research surveyed in this forum rarely peers beneath the waves" (2006: 271). To write the history of the ocean requires consideration of its third dimension, a project that calls for new methods and questions, different from ones used to study the ocean as stage or highway.

Environmental history, which queries relationships between people and nature, seems an obvious tradition to inform ocean history. Yet the sea has until recently been almost entirely absent from this field. Early years of the journal *Environmental History* and its predecessors reveal a preoccupation with such topics as forests, agriculture, water quality, and nature. With a sparse handful of exceptions, the ocean is missing from the journal, although several articles studied fishing industries (Pisani 1984; Bogue 1987; McEvoy 1987). The exceptional contributions to environmental history of the oceans are: an examination of Alaskan whaling; a study of international cooperation in the sealing industry; and a chronicle of efforts by a wealthy French engineer to extract energy from the sea (Leibhardt 1986; Dorsey 1991; Pittman 1982). An additional contribution from a political scientist characterizes oceans, along with other environments including the seabed, Antarctic, airwaves, and orbits of satellites, as international commons, subject to the same misuses as local and national common lands but faced with the additional challenges of international law (Soroos 1988).

Several traditions within environmental history offer models, methods, or perspectives to historians of the ocean, including histories of inland water and waterways and histories of fisheries. It is a testament to the landlocked nature of history that Donald Worster felt compelled to state: "Water has been critical to the making of human history....To write history without putting any water in it is to leave out a large part of the story" (1985: 19). Worster's story of water in the desert West explicates American democracy or lack thereof, but his work also illustrates how a place came to be characterized by interactions among ecology, water, and historical context. A similar approach could analyze how the ocean has been variously understood and experienced as desert, cornucopia, lawless realm, and familiar territory. Other histories of inland water suggest ways to account for characteristics of the sea such as the role of technology in knowing and using maritime environments and the lack of control people have over them (Steinberg 1991, 2000; White 1995).

Fisheries, which deal directly with ocean resources of paramount importance for people, will be a critical theme in ocean history. Much fisheries history excels at revealing social dimensions of the industry, enumerating the different, often conflicting interests of groups of fishers. Those fisheries historians who explore the interplay between social and ecological change provide the best models for a history of the ocean. Outside of work connected to HMAP, the most useful examples are those that bridge environmental history and history of science. Arthur McEvoy (1986), for example, examines California's numerous fisheries and heterogeneous groups of fishers, tracing the legal status and treatment of the resources and investigating efforts to learn about important fish populations in the state's waters. The work of Gregory Cushman (2003, 2005), Christine Keiner (2009), and Jay Taylor (1999) likewise contribute histories of Peru's marine environment, the Chesapeake Bay, and the Columbia River system as elements of studies of industries relying on seabirds, anchoveta, oysters, and salmon. An unusual trajectory of fisheries history, which explores the meanings and practices of eating whales, extends the bounds of environmental history and suggests novel ways historians might integrate culture into studies of fisheries (Oslund 2004; Shoemaker 2005).

Historians of science have a somewhat longer record of attention to the ocean. Until about two decades ago, historians concentrated on laboratory sciences almost to the exclusion of sciences practiced out of doors. By now, however, sciences ranging from natural history to glaciology to meteorology to public health have attracted historical study (Kuklick and Kohler 1996). Independent of this trend, a small but active cadre of historians, scientists, and popularizers had made oceanography's past their subject (Deacon 1971; Schlee 1973; McConnell 1982; Mills 1989). Meanwhile, historians of biology explained the development of marine research laboratories from the late nineteenth century (Benson 1988a, 1988b; Maienschein 1988). Fueled by the growing interest in field science, these strands came together when historians of oceanography, marine biology, and geophysical sciences met at Woods Hole in June 1997 to discuss the state of the history of oceanography, agreeing on the pressing need to pursue more profound understanding of past scientific efforts to comprehend the sea. That meeting spawned a series of workshops on the history of oceanography that resulted in the publication of two volumes and numerous published papers (Day 1999; Rozwadowski 1999; Allard 2001; Oreskes 2001; Rainger 2001; van Keuren 2001; Weir 2001a; Rozwadowski and van Keuren 2004; Benson and Rozwadowski 2007).

Those unfamiliar with this field may not realize how central oceanography has been in the post-World War II landscape, but the burgeoning body of scholarship in history of the ocean sciences makes this fact amply clear. In terms of funding levels and relevance to military and security concerns during the Cold War era, physical oceanography rivaled or exceeded physics

(Mukerji 1989; Hamblin 2005). Since the Cold War's end the ocean has, if anything, increased in importance as a research site for issues related to security for global shipping, to overfishing, and to global climate change. Much of the history of oceanography, as a result, documents the development of various branches of marine science, explores the effects of patronage on oceanography, and queries the relationship between science and the state (Mills 1989, 2009; Oreskes 2000; Oreskes and Rainger 2000; Weir 2001b; Hamblin 2008).

While much history of oceanography chronicles the development of the science itself, some addresses the ocean directly, asking questions about how science has acted in conjunction with politics, culture, and economics to define the sea. For example, a project that began as a study of the origins of modern oceanography revealed the co-contributions of science and culture to the mid-nineteenth-century discovery of the deep ocean (Rozwadowski 2005). That mid-century discovery of the ocean's third dimension was inextricably tied to imperial expansion, a theme also explored by Michael Reidy's (2008) study of tidal science. Noting that shipping, as the cause and consequence of industrialism, required Britain to promote freedom of the seas, Reidy argued that knowledge of the ocean was critical for the extension of its power across the globe. Ability to predict the tides enabled the exercise of imperial power due in part to the ease with which representations of knowledge of the oceans – not only tidal charts but also graphical depictions of magnetic variation, bathymetry, and current patterns – could be passed between men of science and mariners. Before the ocean could be transformed into the first-order site of British imperialism, changes that people wrought to the banks of the River Thames, drastically altering its tides, prompted the renewal of tidal studies in the first place. As good environmental history should, Reidy's work considers the mutual influences of people on the ocean and the ocean's effects on human history.

Some of the best models for writing the history of the ocean to emerge from this trajectory grapple with places such as the polar regions or cultural categories such as "wilderness." Environments such as the poles, atmosphere, "wilderness," and mountains share some characteristics with oceans. A group of historians, examining oceanography done in polar seas, found these regions on the fringe of civilization central to the practice of ocean science, due in part to the importance of the poles at such disparate times as the search for Sir John Franklin and the Cold War. What occurred in the Arctic and Antarctic, both on the ice and in the surrounding seas, reflected cultural and social forces in the homelands of the explorers and scientists and, in turn, redefined these natural environments (Benson and Rozwadowski 2007). Similarly, Gary Kroll's (2008) study of twentieth-century ocean explorers considers the interactive contributions of science and popular culture to shifting American conceptions of the ocean. More explicitly than most other ocean historians, Kroll meditates on the ocean's third dimension, both the

actual undersea realm and cultural perceptions of it. He successfully deploys recent scholarly discussion of "wilderness," demonstrating its utility for analyzing the ocean in American culture.

This swell of interest in ocean science could contribute much to understanding past human relationships with the oceans and their resources. The questions asked by historians of science must be augmented with the sorts of questions customarily asked by environmental historians about terrestrial environments and inland waterways: How have human activities changed the deep sea? How has the ocean environment affected human history? And, importantly, how have the powerful cultural associations of the ocean and assumptions about this unimaginably vast environment intersected with human understanding and use of it? Writing history of the oceans, in short, will require an array of tools and questions from various disciplines and several historical subfields whose subject matter has until now only skirted and crossed the seas. The following section explores how the questions, methods, and content of the history of science and technology, and also of maritime history, might contribute to an environmental history of the ocean.

Knowing Nature Through Work

Richard White, in *The Organic Machine*, wrote, "One of the great shortcomings – intellectual and political – of modern environmentalism is its failure to grasp how human beings have historically known nature through work." By work he meant labor. He explained: "The Nisqually knew salmon by catching them" (x). White's argument suggests that historians could use maritime history to learn about the ocean environment through human labor. Certainly, it seems clear that commercial fishers and whalers, like Native American salmon fishers, knew the ocean through work.

Matthew McKenzie (2003, 2004) has demonstrated the extent to which Salem fishermen from the mid-eighteenth through the mid-nineteenth centuries developed and communicated knowledge about the marine environment in the process of catching (and as a result of their motivation to catch) cod in offshore banks. In addition to amassing anecdotal evidence, he also showed, using HMAP data, that these fishermen changed their fishing behavior, moving to different banks at different parts of the season, to accommodate changes in the marine environment, specifically, declines in fish catches. Colonial Boston ship captains likewise accumulated and recorded information about the ocean garnered through their collective navigational experiences (Rosenberg et al. 2005).

In a similar way to cod fishermen and Boston ship captains, whalers played an important role as vanguards of knowledge about the deep ocean. Hunters who turned from disappearing right whale populations to pursue sperm

whales in the early decades of the nineteenth century were essentially the first people to encounter the ocean's great depths with regularity. "Deep" sea soundings in those decades were rare, undertaken, interestingly, by a handful of Arctic and Antarctic explorers, such as Sir John Ross and his son Sir James Clark Ross. Navigators were surprisingly uncurious about the depth as long as they sailed in water deeper than the standard 200-fathom deep-sea sounding lines they carried. Away from coasts, ruling out shallowness was more important than measuring precise depth. Whalers, on the other hand, quickly found that sperm whales dove deep when harpooned, sometimes taking hundreds of fathoms of line. Occasionally, whaleboats pulled far under would be recovered, waterlogged from the pressure under water. Whalers, who targeted calves in order to keep the mothers nearby for easier pursuit, wondered about the ability of whales, especially babies, to withstand the great pressures. They also wondered if whales, like fish, could be more commonly found over certain types of bottom. Whalers' "fish stories" began to appear in books by the first generation of professional scientists to write about the ocean, such as the British naturalist Edward Forbes and his countryman, the microscopist George Wallich. Whalers brought to the attention of scientific readers fascinating questions about the deep sea (Samuels and Tyack 2000; Rozwadowski 2005).

These examples suggest, not surprisingly, that humans have known the ocean through work such as fishing and navigation. Less familiar may be the suggestion that marine science can be understood as another type of work through which humans have come to know the sea. But first it is necessary to explore the dimensions of what White meant by work.

In White's (1996) essay, "Are You an Environmentalist or Do You Work for a Living?" he pointed out the propensity of American environmental historians to treat premodern work as having benign consequences for nature yet demonize modern work with machines as bad for the environment. White argued that all modern work changes the natural world, citing the electricity powering his computer as coming from a dam that kills fish. Work of all kinds links people to nature and creates knowledge of the land (and, presumably, the ocean), but it does not necessarily grant any protection to the land (whalers began to pursue sperm whales after decimating right whale populations). In White's view, modern work, both that done with industrial machines and that which appears to tread lightly on the earth, affects nature but also opens up the possibility for people to know nature.

In *The Organic Machine* (1995), White concentrated on the theme of energy – the energy of the river and the energy of human work and, especially, how these were related. For the purposes of this essay, the theme of energy is less central than how the labor involved in harvesting fish – or scientific specimens – was an integral part of the process of knowing the oceans. White observed that Indians, gill-netters, and sportsmen did not take salmon primarily for profit, but fished because the act of catching

salmon was tied to who they were. Salmon knit together the energy of the land and the sea; they knit together human and non-human labor; and they defined the Columbia River for millennia. But in addition to natural objects/resources, human creations also came to have an inextricable relationship with it. Dams, hatcheries, channels, pumps, and cities are products of human labor that link people to the river.

Moving from the Columbia River to the Atlantic Ocean, naturalists in the mid-nineteenth century began to collect and study marine flora and fauna. They did this, of course, not mainly for financial gain. Interest in marine creatures was fanned by the growing popularity of seaside holidays and aquaria, and also by developments in natural history that prompted questions about marine life, such as its relationship to fossils. A group of British naturalists and others in Scandinavia and the US began collecting marine organisms using converted oyster dredges. From the 1830s to the 1870s, they reached steadily deeper into the sea until they proved, through the HMS *Challenger* expedition, that life existed in all depths of all oceans (Rozwadowski 1995).

Like White's salmon fishers, these men of science, and the many seamen who helped them (common sailors, officers, paid yachting hands, fishermen, etc.), came to know the oceans through work. Some men of science helped with the physical labor of hauling in the dredge. Most participated in the work of voyaging and inspecting animals on the spot, at sea; most also shared the labor – both physical and intellectual – of transforming the animals collected in their nets into scientific specimens.

Historian of science Robert E. Kohler (1994) has investigated similarities between scientific work and other kinds of labor. Invoking E. P. Thompson's term for the system of implicit rules and moral assumptions about the rights of social classes to the fruits of production, Kohler argued that every system of production – including the production of scientific knowledge – has a "moral economy" that regulates access to the means of production and the goods produced (in the case of science, credit for discovery, for example). This insight prompts historians of science to consider science as a process that starts with the collection of natural objects or information about nature and ends with the publication and use of new knowledge. Keeping this in mind, it is time to return to environmental history.

In *Nature's Metropolis: Chicago and the Great West* (1991), William Cronon described the transformation of natural objects (resources) into commodities and, even eventually, into ideas. He began with the first Euro-American prairie farmers, who transformed grain – by making it into whiskey or feeding it to pigs – into a commodity that could be more easily transported. Merchants participated in the transformation of grain into a commodity by buying, storing, shipping, and reselling it – in short, by linking the farm to the trade of a wider world. Grain, initially transported and sold in sacks, was moved down rivers to cities. The railroad, and the attendant

industrialization, including steam-powered grain elevators, provided new routes for it. A standardized system of grading grain led to the discarding of sacks in favor of flows of similar-quality grain. Elevators, grading, the telegraph, and the creation of the Chicago Board of Trade together revolutionized the grain market, liberating it from the very process that had once defined it – physical exchange. Cronon summarized this process: "Chicago's great innovation ... had been to simplify the natural diversity of wheat, corn, and other crops so that people could buy and sell them as homogeneous abstractions" (1991: 132).

The transformation of grain (or pigs and wood) into the abstraction of futures bears a strong resemblance to how scientists wrought marine fauna and flora into the abstraction of ideas – that is, knowledge about the ocean. Consider the production of knowledge by nineteenth-century naturalists (Allen 1976; Rudwick 1985; Larsen 1993; Farber 2000). Anne Larsen studied the emergence and development of zoology in the first half of the century, as it branched into the specialized subfields of entomology, ornithology, and marine zoology. Zoology grew in the absence of central institutions that historians had assumed were essential to foster new fields. Instead of a national museum, she identified networks of zoologists who corresponded with each other and exchanged specimens. Martin Rudwick previously described such networks of geologists. The sum total of the specimens held by zoologists, geologists, botanists, or other specialists in private collections functioned as a *de facto* national, indeed international, resource that served as the basis for the development and differentiation of natural history into specialty fields.

For present purposes, detailed consideration of natural history practice provides an understanding of how animals were transformed into scientific specimens. Collectors learned from experienced naturalists how to find and catch desirable species. From the animals or plants gathered or captured on a given day, naturalists selected the ones they judged best suited for their purposes; not every collected plant was destined to become a scientific specimen. Sketches of the fresh specimen recorded details that would be lost in preservation. Knowing what kinds of perishable information to preserve was part of the skill set of naturalists, and a preserved animal or plant without this information was not a good specimen (Larsen 1993; Allen 1976).

Creating a specimen out of a dead animal or plant was only the first step. The actual specimens formed a kind of currency in the zoological community, exchanged for information, other specimens, training, expertise in species identification, and access to the tight-knit virtual community of practitioners interested in specialized subfields (Larsen 1993). Experts devoted time to corresponding with enthusiastic amateurs because they could provide unusual specimens or collections from out-of-the-way places (Rudwick 1985). Experts, and also some amateurs, then published species identifications, an abstraction of the physical specimen into knowledge that could be

transported easily, via the printed page. Individuals and scientific societies exchanged publications more readily than specimens, providing a wider radius for the distribution of new knowledge (Farber 2000; Kohler 2006).

The mid-nineteenth-century transformation of marine animals and plants into specimens, and then into knowledge about the sea, has analogs for physical science of the ocean and also for later periods. Hydrographers in the nineteenth century measured the depth of the sea using sounding instruments. They recorded these measurements, along with the particulars of each sounding event, in order to support and analyze their results. Next, they inscribed the numbers on charts and drew depth isobars. The resulting bathymetric charts represented the ocean floor and provided support for transatlantic submarine telegraphy (Rozwadowski 2001; Hohler 2002). In twentieth-century fisheries science, research trawling provided scientists with specimens from which they extracted otoliths (ear bones), used to determine the age of the fish. Data on age, size, and sex of a sample of fish could be extrapolated to assess the age structure of a population – a tool which fisheries biologists used to predict future stock size and the probable effects of proposed fishery regulations (Rozwadowski 2002).

Government white papers and scientific publications translated fish bones, observations, measurements, and equations into scientific knowledge and also policy advice. Bathymetric charts, publications in zoology journals, and policy advice, then, resemble the dams, hatcheries, and other products of human labor that White described as linking people to the environment. They are the products of long processes involving the transformation of nature into transportable and usable ideas. They enabled, even encouraged, the exploitation of the sea and its resources. For example, the earliest deep-sea sounding project was connected to the first transatlantic telegraph cable (Rozwadowski 2001). New knowledge (even if it was imperfect, as it turned out) lent confidence that translated into availability of capital and engineering resources to lay cables. An example involving zoology was the discovery and naming of Pacific marine invertebrates, which reflected the exercise of cultural imperialism by serving as a means of "claiming" the ocean in the name of the nations that sponsored expeditions, in much the same way as did the collection of plants for Kew Gardens, the mapping of India, and polar exploration (Brockway 1979; Edney 1997; Burnett 2000; Robinson 2006). A final example is how the industrialization of fisheries at the end of the nineteenth century made knowledge about the sea pressing enough to promote lasting international cooperation in fisheries science (Rozwadowski 2004). The current tight, if uneasy, links between science and policymaking in fisheries emerged as a product of the work through which fisheries scientists knew nature.

The ocean is very difficult to know. If modern science is a form of work, then efforts to tell the environmental history of the oceans (as well as other remote or difficult environments) must include the knowledge systems,

technologies, and practices of science. Indeed, in the case of vast, opaque environments such as the sea, science appears to be critical to the project of knowing. So is technology. Implicit in the argument for studying not just knowledge of the ocean but its production is the need to recognize, in addition to the history of science, the related but distinct fields of history of technology and science and technology studies (STS). Machines, gear, tools, instruments, and skills have been critical to the development of conceptions of the ocean, particularly those parts otherwise inaccessible to people, but also simply to account for the immense dimensions of the sea (Rozwadowski and van Keuren 2004). More attention to the roles and contributions of technology offers rich possibilities for ocean history. Because of the critical significance of science as a way of knowing the ocean – and of the technologies that mediate knowledge of the sea – the environmental history of the ocean should be guided not only by the questions and methods of environmental history but by those of the history of science and technology as well.

Conclusion

The transformation of natural objects retrieved from the ocean into knowledge provides information about this inaccessible place, but it also does much more. Because people can only know the sea indirectly, knowledge – whether derived from subsistence activities, commercial or industrial work, or science – actually constitutes the ocean. People know the ocean through technologies and knowledge systems such as compasses, charts, and navigational knowledge, or nets, bait, and knowledge of how to find fish. Scientific knowledge, then, numbers among the ways that people know the ocean environment, alongside other kinds of work such as fishing, reconfiguring coastlines, building and operating vessels, and so on.

To understand the human relationship with the sea – a goal of environmental history – it will be essential to look at how knowledge about the ocean has been produced: by whom, with what kinds of instruments or tools, using what kinds of practices – whether scientific, industrial, or recreational – in which historical contexts, and for what intended uses. The fields of history of science and history of technology attend to the intellectual, political, and social factors that influence the development and deployment of various tools and knowledge systems. Telling the history of the ocean will, therefore, engage environmental historians in questions similar to those asked by historians of science – questions about how knowledge of such a remote and inaccessible environment was created, and how that knowledge was subsequently used. The questions and methods of history of science are just as relevant to understanding knowledge produced by ship captains and fishermen as by Cold War physical oceanographers.

Writing the history of the ocean, then, will likely fuse the framework of environmental history to questions and methods from history of science and technology. It will also, as this essay argues, draw from a variety of other fields and methodological traditions. The questions and perspectives of maritime history, especially, elucidate the labor that allows people to know the oceans. Geography contributes ways to comprehend and analyze vast spaces, both horizontal and vertical, that comprise the ocean. Anthropology and sociology offer means for understanding cultural and social constructs that relate to the ocean, while literary studies inform intellectual and cultural conceptions of the sea. The lessons to be learned about how to tackle the telling of environmental history of the ocean may also illuminate the task of studying the human relationship with other remote, inaccessible places including the poles, rainforests, mountains, the atmosphere, space – the kinds of places that are known as much through imagination as through direct experience. Places closer to home can, of course, also be known through imagination; histories of the ocean and other ends of the earth may turn out to be central after all.

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