WHERE SCIENCE MEETS THE SEA:
RESEARCH VESSELS AND THE CONSTRUCTION OF KNOWLEDGE IN THE NINETEENTH AND TWENTIETH CENTURIES

by
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A dissertation submitted to Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy

Baltimore, Maryland
April 2017

ABSTRACT

This dissertation focuses on the ocean-going research vessel as the fundamental technology of marine scientific investigation by examining a series of ships from Great Britain, Monaco, Germany, and the United States, all built or extensively converted for the purpose of pursuing marine investigations in situ from the mid-nineteenth through the end of the twentieth centuries. It argues that oceanographic ships have served essential symbolic purposes—for individuals, disciplines, patrons, and political entities—even as they have been tools of science and platforms for the development of knowledge of the oceans, and it explicates the co-construction of ocean science, technology, and the career path of the oceanographer during this period. Knowledge of the ocean as a dynamic environment heavily depends upon the practices and technologies of ocean science. By illuminating this relationship, this dissertation uses the history of science and technology to historicize an environment often assumed to have no history.

Case studies examine US naval officer Matthew Fontaine Maury's studies of the ocean-atmosphere system as a means to increase the safety and reliability of commercial shipping in the mid-nineteenth century; the British scientific circumnavigation by the HMS *Challenger* expedition, jointly sponsored by the Royal Society of London and the Admiralty in the 1870s; Prince Albert I of Monaco's use of custom-built personal yachts as platforms for oceanography and meteorology during the period from 1884 to 1921; the cooperation between German scientists and naval officers to refit the newly-built gunship *Meteor* for ocean-going research in the 1920s; and the use of Cold War-era scientific competition by American biologists to push for the dedicated research vessels that would help them break from the shadow of physical oceanography, which had made significant gains in funding and scale following World War II. The broad chronological and geographical frame provides a comparative canvas on which to examine historical questions surrounding shifting models of patronage, authority, and hierarchy; fluid disciplinary boundaries; and the interplay of culture, class, and gender at the overlap of the scientific and maritime environments.

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ACKNOWLEDGEMENTS

Over the course of this project I have had the incredible fortune of being surrounded by advisors, mentors, and friends who made this a far more pleasant undertaking than one might reasonably expect it to be. Bill Leslie, my advisor, showed an unwavering faith in my abilities from our very first meeting. He has been encouraging and enthusiastic since, supporting anything I could convince him was doable (and more than a few things that he was probably not quite convinced about, but was willing to let me try anyway). He gave me fathoms and fathoms of rope, eternally confident I would not hang myself. So far it's worked! Helen Rozwadowski has likewise been an incredible mentor and advisor-in-all-but-name almost from the beginning. It was she who provided the definition of an oceanographer as a scientist who goes to sea, thus sparking this entire project. Her support and guidance in seeing it through have been invaluable. Ron Walter's patience in letting me formulate my fieldwork broadly as a way to explore and better define my interests was also much appreciated. Yulia Frumer, since her arrival at Hopkins, has also become a much-valued mentor, a sounding board for ideas, and a source of advice. And Anand Gnanadesikan's willingness—even enthusiasm—to teach oceanography to a historian whose last brush with calculus was decades past was much appreciated.

Other faculty and staff at Johns Hopkins have made my experience here a sojourn in a friendly academic community. María Portuondo and Sharon Kingsland, as professors and department chairs, provided me with guidance and intellectual challenge that shaped my academic direction. Larry Principe, Bob Kargon, and, more recently, Joris Mercelis have also been sources of guidance, suggestions, and occasionally very welcome humor at various stages of the project. I also thank Jeremy Greene, Graham Mooney, Nathaniel Comfort, Gianna Pomata, and Christine Ruggere for their interest and encouragement, and for providing insight from new directions that proved valuable. And of course Danielle Stout kept the wheels on.

This research was assisted by a fellowship from the Dissertation Proposal Development Fellowship Program of the Social Science Research Council with funds provided by the Andrew W. Mellon Foundation. The work also benefitted from research conducted as a Smithsonian Libraries' Baird Society Resident Scholar, during which the entire Smithsonian Libraries staff provided enthusiastic help, especially Leslie Overstreet and Daria Wingreen-Mason at the Joseph F. Cullman 3rd Rare Book Library, Martha Rosen at the Natural History library, and Lilla Vekerdy at the Dibner Library of the History of Science and Technology in the National Museum of American History. While at the Smithsonian, I benefitted from the expertise of Caitlin Silberman, also in residence at the time, who made me think more deeply about my artists as sources. The staff of each of the archives I visited provided incredible assistance and hospitality; in particular, I would like to thank Jacqueline Carpine-Lancre, chargée de recherche at the Palais princier de Monaco, for her generous assistance. The dissertation also benefitted from research conducted as a Kenneth E. and Dorothy V. Hill Fellow at the Huntington Library. I thank my fellow Huntington Fellow Therí A. Pickens for sharing her own fascinating work and for letting me go on about mine.

The insightful comments of the participants in the “Practicing Oceanography” workshop during the summer of 2014 greatly improved chapter one; Bruce Hevly and Katharine Anderson were particularly helpful. Several other participants continue to be valuable sources of information, ideas, and conversation, especially Antony Adler, Samantha Muka, Christine Keiner, Robert-Jan Wille, Jennifer Martin, and Megan Barford, none of whom I see as often as I'd like to. My colleagues in the Advanced Seminar of The Johns Hopkins University Program in the History of Science, Medicine, and Technology also provided valuable feedback on this chapter. I was honored to be able to participate in the Workshop for the History of Environment, Agricultural, Technology, and Science at the University of Colorado-Boulder in October 2015; I thank my fellow participants for their feedback on the HMS *Challenger* work I presented there.

I owe thanks to Katherine Arner, Linda Braun, Christopher Consolino, May-Lin Iversen, Jean-Olivier Richard, Marion Schmidt, Robert-Jan Wille, and Hanna Worliczek for translation assistance; to C. C. Finlay for assistance finding mysterious historical locations; and to Jamie Holeman, Dale Clifford, and Antony Adler for advice on handling French-language sources.

My research, my writing, and my mental health have all benefited from the friendship and support of my colleagues at Hopkins, especially Kirsten Moore-Sheeley, Ada Link, Layne Karafantis, Simon Thode, Emily Margolis, Sean Schifano, Yixian Li, Eli Anders, Julia Cummiskey, Emilie Raymer, Richard Nash, James Flowers, Todd Christopher, Marc Alsina, Seth LeJacq, Phoebe Tang, Heidi Morefield, Alicia Puglionesi, Justin Rivest, Sam Scharff, and of course Rex, without whom no gathering is complete.

Jean-Olivier Richard, Jon Phillips, Ayah Nuriddin, Joanna Berhman, Anna Weerasinghe, Matthew Franco, Emily Yoder, and Gabriel Lopes-Anaya have, from time to time, helped me slay dragons. I have become a better and more well-rounded scholar and human being due to the influence of Rebecca Stoil-Shimoni, Amira Davis, Lauren MacDonald, Katie Boyce-Jacino, Jessica Levy, Mo Speller, Morgan Shahan, Jessica Keene, Jennie Grayson, and others I am no doubt neglecting.

Dale Clifford, Aaron Sheehan-Dean, Paul Halsall, David Sheffler, Charles Closmann, and Michael Francis, all of whom I encountered at UNF, provided me with a strong scholarly foundation and then encouraged me to keep going. The continued success of their many students is a testimony to their teaching abilities and dedication. My UNF classmates continue to provide inspiration and serve as role models (though they'd likely deny it).

Finally, I would be remiss if I did not recognize the encouragement and support I have received from my family. You really cannot have better preparation to be a historian of science and technology than having a mathematician and a librarian as parents. My dad inspired me to pursue my PhD, and my mom set an example I've never forgotten by tackling grad school with three young children. My siblings, Jen and Miles, provide exactly the right combination of challenge and encouragement. Last but my no means least, I owe a great debt of gratitude to my husband, Al, who has patiently supported my decision to pursue this goal, putting up with my absence when I'm away for research and with my presence when I'm writing.

Thank all of you, for all of this, and for all the things I'm forgetting.

NOTE ON MEASUREMENTS

I follow my actors in their usage of fathoms, metric, or imperial units to measure depth. Sometimes, especially early in the chronology, the same actors used different standards in different places. This reflects both the nature of a field that had not yet agreed upon consistent usage and the frequency with which they moved between different audiences. For instance, for a lay audience at home, nineteenth-century British naturalists might record depth in fathoms (a unit equal to six feet), but for a scientific audience, especially a continental European one, they might switch to meters. Temperatures were similarly recorded in degrees Celsius or Fahrenheit, or pressure in various formats, and I have again kept the original units

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INTRODUCTION

Obviously, therefore, the progress of oceanography depends to a great extent upon the development of mechanical aids, by which we mean not only the scientific instruments employed, but also the whole arrangements of the ship itself.

-- Johan Hjort[1]

An understanding of the marine sciences—or, indeed, of the human relationship with the oceans—requires an examination of the ways in which knowledge about the marine environment is produced. For marine science in particular, this means examining the technologies of science. Norwegian marine scientist Johan Hjort, quoted above, described studying the ocean depths as "like hovering in a balloon high above an unknown land which is hidden by clouds."[2] The depths of the ocean, in other words, are invisible and inaccessible without technology. Technology has thus always dictated what we know of the sea, how we know it, even what questions we can ask and how we interpret the answers. The technologies used to acquire scientific oceanic knowledge become necessarily embedded in the knowledge produced, just as scientific knowledge (and its component theories and anticipated results) drive the development of technology. These include, as Hjort describes them, the "instruments and appliances" sunk "from time to time . . . into the deep."[3] But chief among them, the technology without which the instruments could not hover above nor be lowered through the metaphorical clouds, is the ship.

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[1] John Murray and Johan Hjort, *The Depths of the Ocean: A General Account of the Modern Science of Oceanography Based Largely on the Scientific Research of the Norwegian Steamer* Michael Sars *in the North Atlantic* (London: Macmillan, 1912), 22. Hjort identified himself as author of the chapter in which this quotation appears, vii.

[2] Ibid., 22.

[3] Ibid.

Beginning in the mid-nineteenth century, scientific investigators in Europe and the United States became increasingly interested in the deep sea as an object of study. They accessed this new arena by rowboat and eventually, as yachting culture grew, by increasing larger boats, adapting the tools of those who harvested sea life as food—fishers, oystermen, and others—and often hiring these workers to operate the adapted equipment or to instruct them in its use. Eventually naturalists decided they needed larger vessels, and they increasingly partnered with patrons who possessed them. Frequently this meant navies or other government entities. The development of oceanography, which is usually considered to have been firmly established in the last quarter of the nineteenth century, thus involved the co-creation of a new conception of the sea bottom, the scientific methods for studying it, and the technological means of reaching it.[4]

There was nothing inherently new about the "discovery" of the sea in this period; human beings had speculated about its geological structure and the nature of its inhabitants for thousands of years. Aristotle considered the origin of the sea in his fourth-century BCE *Meteorologica* (as, for that matter, did the Judeo-Christian book of Genesis).[5] The seventeenth-century scientific revolution brought renewed interest from such thinkers as Athanasius Kircher and Robert Boyle, who cited their predecessors' ideas to speculate on

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[4] The term oceanography was apparently coined in German in about 1857, when it is was used by naval physician August Jilek in the title of his *Lehrbuch der Oceanographie zum Gebraucht der k. k. Marine-Academie* (Vienna, 1857), though Jilek was summarizing the state of the field rather than doing original research. He concluded for the most part that the physical processes of the oceans were poorly understood if at all, and he summarized the work of Matthew Fontaine Maury (see chapter 1, below). In English, the term was apparently first used by Maury in 1859 reference to Jilek's textbook, then made isolated appearances in the ensuing decades and only entered widespread use following its employment in the *Challenger* results volumes (see chapter 2, below).

[5] Aristotle had implied the role of ships in studying the deep when he discussed, for instance, the variable salinity of water near or far from shore, but the vessels themselves did not appear. Aristotle, "Book XXIII. Problems Connected with Salt Water and the Sea," *Problems,* in *The Complete Works of Aristotle,* ed. Jonathan Barnes, vol 2, (Princeton: Princeton University Press, 1984), 1463.

the nature of the sea bottom and of salinity. Yet Kircher, for all his enthusiasm concerning technology and his famously hands-on approach to volcanology, apparently remained an armchair philosopher when it came to the study of the sea.[6] Boyle, however, offered the beginnings of a plan of investigation, and one that required ships to reach their object of study. He considered evidence on the ocean's temperature, salinity, bottom morphology, and pressure, citing in the last case the example of a wine bottle whose cork was inconveniently well-seated by the pressure at depth after being dangled over the side to chill.[7] As had his predecessors, though, Boyle was relating a story told to him by someone else, rather than his own experience at sea. After all, if he "d[id] not pretend to have visited the bottom of the sea," then neither had anyone else who wrote about it.[8] The titular experiments he relates in "Experiments and Observations upon the Saltness of the Sea" occurred in his usual, shore-based laboratory or in nearby rivers, performed in glass vessels "of a convenient depth" upon seawater that was no doubt brought to him by others.[9] He suggested means of studying the ocean, and even designed an instrument for testing salinity, but did not undertake such study himself, and noted that it was "a great rarity in those cold parts of Europe to meet with any men at all, that have had at once the boldness, the occasion, the opportunity, and the skill to penetrate those concealed and dangerous

[6] This is the barest list of the thinkers addressing the nature of the oceans over time. A much larger number attempted to solve the problem of explaining (and predicting) the tides, as for instance did Galileo Galilei in his "Discourse on the Tides" (1616). Notably Galileo's ideas proceeded from his observation of the behavior of a liquid cargo during a ferry ride, but he did not directly sample the sea itself. For a good summary of thinking on the topic throughout the period, see the first three chapters of Margaret Deacon, *Scientists and the Sea, 1650-1900: A Study of Marine Science* (London: Academic Press, 1971).

[7] Robert Boyle, "An Hydrostatical Discourse, Etc.," in *The Works of the Honourable Robert Boyle, in Six Volumes*, New edition, vol 3., 599-628, (London, 1772): 624-5.

[8] Robert Boyle, "Relations about the Bottom of the Sea," in *The Philosophical Works of the Honourable Robert Boyle*, vol 3, ed. by Peter Shaw, 349-354 (London, 1725), 349.

[9] Boyle, "Experiments and Observations upon the Saltness of the Sea," in *Philosophical Works*, 214-231: 217-218.

recesses of nature, much less to make any stay there."[10] The Royal Society of London was in 1661 interested enough to prepare a list of suggestions for observations to be done onboard a naval expedition, but not to undertake such work themselves.[11]

The change that happened over the course of the nineteenth century, then, was not a sudden interest in the sea so much as a sudden willingness to experience it, the results of which then created a growing interest in studying it, in a kind of feedback loop. Helen Rozwadowski has tied this "discovery" of the sea as a place to do science to its discovery during the same period via the fruits of the Industrial Revolution, whose railroads made the seaside accessible as a recreational destination and whose steamships made ocean-going travel more predictable and accessible to a wider audience.[12]

While the remoteness and inaccessibility of the deep sea make technology necessary for its study, there is no inherent requirement for ocean researchers to be themselves ocean-going. For a counter model, one need only look at the examination of oceans and atmospheres in the rest of the solar system, and indeed at the ongoing argument in the United States over human versus robotic spaceflight.[13] Models of office-bound scientists can be found in all of the examples listed above, who speculated on the oceans like Kircher, who theorized based on the data of others like Boyle, and who wrote detailed instructions for the collection of more data. From the shore, they could suggest or design

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[10] Boyle, "Relations about the Bottom of the Sea," 349.

[11] Deacon, *Scientists and the Sea*, 74.

[12] Helen M. Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea*. Cambridge, MA: Belknap Press, 2005.

[13] Erik Conway discusses earthbound science as analogue for offworld planetary science in his *Atmospheric Science at NASA: A History* (Baltimore: Johns Hopkins University Press, 2008). See, for example, page 318. NASA use the language of planetary exploration in its reference to the first dedicated oceanographic satellite, the 1978 SEASAT, as a "mission to earth"; Jet Propulsion Laboratory, "Mission to Earth: Seasat," accessed 19 March 2017, online at https://www.jpl.nasa.gov/missions/seasat

technologies and improve those designs in response to results. In interpreting results, they could imagine an ocean bottom that, while it might be thousands of miles further from their armchairs in actual physical space, was hardly any more distant from their chairs than from the ship's deck in terms of physical experience.

This model of science did not pass into obsolescence. Indeed, many of those in the nineteenth century who processed the samples gathered by seagoing proto-oceanographers and who wrote up the results of these expeditions did so ashore in the US and Europe. Matthew Fontaine Maury, the central figure in chapter 1, below, proceeded on exactly this model, though he even added another layer of distance between the scientist and the sea bottom by acting as a middleman for samples from the Atlantic which were sent for analysis to shore-bound naturalists like the microscopist Jacob Whitman Bailey at West Point.[14] The Stazione Zoologica, founded in 1872 in Naples by German biologist Anton Dohrn, provides another shore-bound example: biologists from across Europe rented tables at the shore station and placed orders for the organisms they wished to study, which were harvested by others and delivered to their tables.[15] This model could have remained the dominant one for deep water biology, physics, geology, and chemistry as well. It might have created a different perception of the ocean, but not necessarily a less accurate one. It certainly would have created a different career model for researchers.

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[14] Lee, S[amuel] P[hillips], and H. C. Elliott. *Report and charts of the cruise of the U.S. brig Dolphin, made under direction of the Navy Department*. 699 S.exdoc.59 (1854), [342].

[15] Antony Adler has demonstrated that in reaction to this, a belief in gathering one's own specimens became a key part of the formation of shore-side marine laboratories in France during the nineteenth and into the twentieth century. See his "The Hybrid Shore: The Marine Station Movement and Scientific Uses of the Littoral (1843-1910)," chapter 2 in "The Ocean Laboratory: Exploration, Fieldwork, and Science at Sea," Ph.D. Dissertation (University of Washington, 2014), 68-124.

Yet proto-oceanographers chose to go down to the sea in ships, and they argued for the necessity of doing their scientific business on the great waters. This decision made of their ships a new kind of vessel, at least reimagined and often physically redesigned and reorganized for the purpose of conducting science in situ. The ship also thus served as an important focal point for the coalescing scientific field of oceanography, and it became integral to the career path of those who wished to pursue it. Because oceanographers went to sea, the action became essential to the definition of oceanographer, embracing an element of adventure and even heroism as necessary to the conduct of science.[16] Those who stayed ashore might be marine biologists or physicists or chemists, but they were not oceanographers. And those who did not have access to ocean-going ships—whether because of their social class or their politics or their race or gender—found it increasingly difficult to pursue careers in ocean science.[17]

The ocean-going research ship thus serves as a useful focus of study for a number of reasons. Because of the coincident occurrence of this ocean science revolution with the industrial revolution—and by coincident here I do not mean coincidental—the technologies of and on these ships was in flux throughout the period. That instability thus informs our understanding of the scientific practice they were designed to facilitate. Ships also allowed intimate contact with the ocean environment just as that environment was

[16] At least for the early parts of their careers. Senior scholars became increasingly likely to stay home and process results, but the early, oceangoing career phase remained the necessary standard throughout the twentieth century. Oceanography arguably grew from Matthew Fontaine Maury's pursuit of a Humboldtian physical geography of the sea, as described in chapter 1, below, and in fact this early adventure-later armchair model reflected the progress of Alexander von Humboldt's own career.

[17] Naomi Oreskes has argued that the objection to the full inclusion of women in science often hinged not on an oft-supposed lack of objectivity but in fact on their exclusion from this kind of heroic science, such as that done at sea. "Objectivity or Heroism? On the Invisibility of Women in Science," O*siris*, 2nd Series, Vol. 11, *Science in the Field* (1996): 87-113.

being created as a theater for science. This left scientists and their mariner partners large scope to adapt, remake, and invent the tools of their trade to meet needs perceived or encountered on the deep. These redesigns thus reflected their oceanic experience, and changed in response to their scientific results but also drove the collection and interpretation of those results.

That scientist-mariner partnership is also part of the story. The voyages required to access the deep sea necessarily brought a diverse group of actors together in isolation, and these actors' varying expertise was required to reach and interpret the bottom. The technologies of ocean science were thus created through the contributions of people of various backgrounds, with different skills and sometimes competing motivations, making them contingent on this idiosyncratic combination of people. The ensuing interpretation of the oceans became equally contingent, reflecting the aims and understanding of its multiple contributors. Exploring the relationship between technology and scientific and environmental knowledge thus also allows the examination of the personal experience and practical knowledge of a broad group of actors.

Identifying the ships and the actors who designed, operated, and funded them also allows us to get at motivations and intentions. Even when it is practiced in a lonely ship on a distant ocean, science always exists within society. It is thus inherently political. Each of these ships, then, served political purposes, as did their scientific activities, even as they collected data and produced results that were—in general—freely published to an international audience. Those politics might be individual, disciplinary or interdisciplinary, and national or international. They were usually all of these things.

These politics are reflected in funding discussions, in crew selection, and in design decisions. Focusing on ships thus provides a window on ocean science as politics, an angle usually examined only on the national or international level and often only through policy documents and committee minutes.

HISTORIOGRAPHY

Though ships are obviously important tools of the trade for oceanographers, they are often invisible in the scientists' published results, which may explain why historians of science have largely taken such vessels and their uses for granted, and historians of technology have not engaged them. This is part of a trend historian Helen Rozwadowski has called an "overall benign neglect of the sea" and perception of "the ocean as apart from history" which is shared "by many historians, who treat the sea as backdrop for human activities rather than as a place susceptible to, and involved in, historic change." Because of its extent and the challenges of observing its depths, "knowledge of the sea is [necessarily] mediated by technology and knowledge systems," so, Rozwadowski suggests, "[o]cean history will have to incorporate technology and the creation of knowledge as fundamental constituents."[18]

Following Rozwadowski's lead, this dissertation centers the global ocean environment as a site for the production of both scientific knowledge and technology, and thus as a historical place. While important work has considered maritime communities

[18] Rozwadowski, "Ocean's Depths," *Environmental History*, 2010, *15*: 520-525, on pp. 520, 521, 524. This point is reiterated in Keith R. Benson, Helen M. Rozwadowski, and David K. van Keuren, "Introduction," in *The Machine in Neptune's Garden: Historical Perspectives on Technology and the Marine Environment*, ed. Rozwadowski and van Keuren, xiii-xxviii (Sagamore Beach, MA: Science History Publications, 2004).

both ashore and afloat, only recently have historians begun to address their attention to the sea itself. While ships of exploration certainly existed before the nineteenth century, the vessel intended and especially equipped for a scientific mission with the ocean as its specific object of investigation emerged at a time when the Humboldtian call to classify and catalog the world's landmasses led some to imagine similar investigations of the oceans, and at a time when the burgeoning industrial revolution applied its methods and products to crossing and harvesting the oceans. The juxtaposition of science and technology drove both interest and opportunity to investigate the depths during a flowering of cultural discovery of the sea elucidated by Helen Rozwadowski, as well as in the intellectual milieu from which the first modern definitions of science and conceptions of scientists as professionals arose, as Michael Reidy has examined.[19]

As has been noted, few historians have concentrated on the technologies of ocean science. Historians of fisheries science like Carmel Finley and Jennifer M. Hubbard examine extractive technologies that enable and/or endanger maritime harvest, but the scientists they study generally considered these implements from the safety of the shore. When they used ships, it was for voyages of short duration and local focus, or with the employment of floating marine biological station.[20] This is not to say larger ships were not equipped for fisheries science—they were—or that such science did not provide the motivation for longer cruises. The US Fisheries Vessel *Albatross*, for instance, is often

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[19] Rozwadowski, *Fathoming the Ocean: the Discovery and Exploration of the Deep Sea* (Cambridge, MA: Belknap Press of Harvard University Press, 2005); Reidy, *Tides of History : Ocean Science and Her Majesty's Navy* (Chicago: University of Chicago Press, 2008).

[20] Finley, *All the Fish in the Sea* (Chicago: University of Chicago Press, 2011). Hubbard, *A Science on the Scales: The Rise of Canadian Atlantic Fisheries Biology, 1898-1939* (Toronto: University of Toronto Press, 2006).

pointed to as the first purpose-built ocean research vessel, and while it has seen some attention from historians, it warrants more.[21] Similarly, Helen Rozwadowski has looked at the history of the International Council for the Exploration of the Sea (ICES), the European fisheries organization founded in 1902; she points to the commitment of each member nation to funding a ship for science, and to the organization's conduct of quarterly research cruises near Europe from its beginning.[22] Still, the focus of these authors has largely been on organizational structure, science policy, and its drivers. Other historians, like W. Jeffrey Bolster, consider technology from the perspective of the fisher, and while marine conservation biologist Callum Roberts, writing for a broader audience, addresses the effects of advancing fisheries technology on fish depopulation. In each case technology remains a concern at least secondary to their primary focus on the environmental effects of extraction.[23]

Works directly engaging the relationship between those who study the oceans and their equipment are few. The archives of Technology and Culture, foundational journal of the history of technology, contain a handful of articles on the history of naval architecture, two on lighthouses, two on marine turbines, a couple on hydraulic and coastal engineering, and but a single article in the journal's history on technical change in an ocean science (in this case the Icelandic fisheries).[24] Historians of oceanography frequently avoid specifically addressing "instrumentation and application" or do so "only insofar as they

[21] See, for instance, Dean Allard, "The Origins and Early History of the Steamer *Albatross*, 1880-1887." *Marine Fisheries Review* 61, 4 (1999): 1-21.

[22] Rozwadowski, *The Sea Knows No Boundaries: A Century of Marine Science under ICES* (Seattle: International Council for the Exploration of the Sea/University of Washington Press, 2002.)

[23] Bolster, *The Mortal Sea: Fishing the Atlantic in the Age of Sail* (Cambridge, MA: Belknap Press, 2012); Roberts, *The Unnatural History of the* Sea (Washington, DC: Island Press, 2007).

[24] Arni Sverrison, "Small Boats and Large Ships: Social Continuity and Technical Change in the Icelandic Fisheries, 1800-1960," *Technology and Culture* 43, no. 2 (April 2002): 227-253

affect the direction of scientific thought," as Susan Schlee has explained her own circumvention of the topic in a 1973 survey of the history of oceanography. (Though Schlee did pen a notable exception in her biography of Woods Hole Oceanographic Institution's R/V *Atlantis*, the book portrays *Atlantis* more as a character in the Woods Hole story than as a technology of scientific practice.[25]) *The Machine in Neptune's Garden*, the results of the 2001 Maury Conference on the History of Oceanography, whose organizers chose "the role of technology in advancing and shaping our understanding of the marine environment" as its focus, stands out for this reason.[26] Anita McConnell in Britain and Christian Carpine in France did important work on the instruments of ocean science as objects of material culture, and a handful of articles elsewhere have addressed the history of oceanographic instrumentation, a subject which certainly merits more such attention.[27] Yet the most fundamental piece of equipment—perhaps the defining piece, without which, at least in the nineteenth and twentieth centuries, an oceanographer was not an oceanographer—is the research vessel, a subject still largely neglected.

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[25] Susan Schlee, *Edge of an Unfamiliar World* (New York: E. P. Dutton, 1973), 17, 18. Schlee, *On Almost Any Wind: The Saga of the Oceanographic Research Vessel Atlantis* (Ithaca, NY: Cornell University Press, 1978).)

[26] "Foreword," in Rozwadowski and van Keuren, eds., *The Machine in Neptune's Garden*, xi.

[27] McConnell, *No Sea Too Deep: The History of Oceanographic Instrument*s (Bristol, UK: Adam Hilger, 1982). Carpine, *La pratique de l'océanographie au temps du Prince Albert Ier* (Monaco: Musée océanographique, 2002); and Carpine, "Catalogue des appareils d'océanographie en collection au Musée océanographique de Monaco," 8 parts in 7 vols of the *Bulletin de l'Institut Océanographique*, including vol 73, no. 1437 (1987); 74, no. 1438 (1991); 75, no. 1440 (1993); 75, no. 1441 (1996); 76, no. 1442 (1997);76, no. 1443 (1998); 76, no. 1444 (1999) The "handful" include Rozwadowski, "Technology and Ocean-scape: Defining the deep sea in the mid-nineteenth century," *History and Technology* 17 (2001): 217-247; Rozwadowski, " 'Simple enough to be carried out on board': the maritime environment and technological innovation in the nineteenth century," in *Teknikens landskap*, ed. M. Hedin and U. Larssen, 83-97 (Stockholm: Atlantis, 1998); Höhler, "Depth Records and Ocean Volumes: Ocean Profiling by Sounding Technology, 1850-1930," *History and Technology* 18 (2002): 119-154; Höhler, "Profilgewinn. Karten der Atlantischen Expedition (1925–1927) der Notgemeinschaft der Deutschen Wissenschaft," *NTM International Journal of History & Ethics of Natural Sciences, Technology & Medicine 10*, Issue 4 (December 2002): 234-246. See also Richard Dunn, "'Their brains over-taxed': Ships, Instruments and Users," in *Re-inventing the Ship: Science, Technology and the Maritime World, 1800-1918,* ed. Don Leggett and Richard Dunn, 131-156 (Burlington, VT: Ashgate, 2012).

When ships are discussed, it is often either in isolation or in statistical abundance. For the former, Dean Allard's aforementioned article on the *Albatross* and Susan Schlee's aforementioned biography of the *Atlantis* examined individual ships.[28] On the other hand, Stewart B. Nelson and A. L. Rice produced works of encyclopedic thoroughness on, respectively, the US research fleet as of 1971 and the British research fleet from 1880 to 1950. The usefulness of both works as reference volumes cannot be overstated, but their purpose is to catalog rather than analyze.[29]

At the same time that historians of technology have stayed ashore, so too have historians of the field sciences and of the lab/field border, such as Robert Kohler.[30] The study of ships, and of science done aboard them, differs in fundamental ways because of the very nature of the ship and of the sea. The invisibility and inaccessibility of the depths make them different than the forest or the desert. Dorinda Outram, in examining natural historians ashore, noted that "to reconstruct the spatial experience of the natural historians of this period, we have to think about not just what they might have seen, but also about what sort of physiological structures might have mediated their response to space. . . . To find out what space perception was, we have to come to grips with the whole-body experience of the men of the past."[31] As sociologist Thomas F. Gieryn has pointed out, "Built places materialize identities for the people, organizations, and practices they

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[28] Allard, "Origins and Early History." Schlee, *On Almost Any Wind: The Saga of the Oceanographic Research Vessel* Atlantis (Ithaca, NY: Cornell University Press, 1978).

[29] Nelson, *Oceanographic Ships: Fore and Aft* (Washington, DC: Office of the Oceanographer of the Navy, 1971). Rice, *British Oceanographic Vessels 1880-1950* (London: Ray Society, 1986).

[30] Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago Press, 2002).

[31] Dorinda Outram, "New Spaces in Natural History," in N. Jardine, J. A. Secord, and E. C. Spary, eds. *Cultures in Natural History*, 249-265 (Cambridge, UK: Cambridge University Press, 1996), 264.

house."[32] If this was true for the Outram's Paris *jardin* and *muséum* and for Gieryn's laboratory buildings, it is even more so of the research ship at sea. Examining their vessels lets us come to grips with these scientists' experience and recognize their materialized identities. Part of that identity, we shall see, comes from their simultaneously being scientists and becoming mariners, and attempting to portray their shipboard laboratories as "truth spots," which would "provide a stable core of placelessness even when enveloped by the field," as Gieryn has argued is the purpose of shore-based laboratories.[33]

A few sociologists of science have engaged ships and their role in science directly. Most influential of these was probably Richard Sorrenson's "The Ship as a Scientific Instrument in the Eighteenth Century." Sorrenson describes a certain pattern of research, when the investigators are sitting ashore in the metropole, while the investigation is carried out by mariners on the periphery, who send their data back for reduction.[34] While this may have been true—to a degree—of his eighteenth century mapmakers, the ships to be considered here vary significantly from this pattern. Anne-Flore Laloë makes this point in her "Where is *Bathybius haeckelii*? The Ship as a Scientific Instrument and a Space of Science." While of course they still send data—and samples—home to be analyzed by the

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[32] Thomas F. Gieryn, "Two Faces on Science: Identities for Molecular Biology and Biotechnology," ch 20 in Peter Galison and Emily Thompson, eds., *The Architecture of Science*, 423-455 (Cambridge, MA: MIT Press, 1999), 423.

[33] Gieryn, "Three Truth-Spots," *Journal of the History of the Behavioral Sciences* 38, 2 (2002): 113–132.

[34] Sorrenson, "The Ship as a Scientific Instrument in the Eighteenth Century," *Osiris* 2d Series, Vol. 11, *Science in the Field* (1996): 221-236. See also Bruno Latour, "Centres of Calculation," ch 6 in Science in Action: How to Follow Scientists and Engineers through Society, 215-257 (Cambridge, MA: Harvard University Press, 1987); and Latour, "The Force and Reason of Experiment," in H. E. Le Grand, ed., Experimental Inquiries: Historical, Philosophical, and Social Studies of Experimentation in Science, 49-80 (Dordrecht: Kluwer Academic Publishers, 1990)

aforementioned shore-bound scientists, Laloë argues that the scientific use of ships has changed by the nineteenth century, when "the ship became fully re-invented as a space of science."[35] I follow and expand her argument here, showing that by the 1860s or 1870s seagoing ocean researchers are notable for their use—and description—of their ships as laboratories, where they conduct their own research and make their own decisions concerning the subject, sequence, and consequence of their investigations rather than serve as distant instruments operated by an invisible metropolitan hand.

Antony Adler also responded to both Sorrenson's and Kohler's models of field science in his "The Ship as Laboratory: Making Space for Field Science at Sea."[36] Adler considers the shipboard environment vital to the development of ocean science, and he notes in particular the remaking of shipboard spaces. In this he follows Rozwadowski's "Small World: Forging a Scientific Maritime Culture for Oceanography," which considered the meanings and redefinitions of space on board HMS *Challenger*.[37] This dissertation expands upon both of their arguments, considering not just the effects of the reassignment of space on board, but also naturalists' own arguments about why shipboard spaces are ideal spaces for pursuing science.

[35] Laloë, "Where is Bathybius haeckelii? The Ship as a Scientific Instrument and a Space of Science," in *Re-inventing the Ship: Science, Technology and the Maritime World, 1800-1918*, ed. Don Leggett and Richard Dunn, 113-130 (Burlington, VT: Ashgate, 2012): 113.

[36] Adler, "The Ship as Laboratory: Making Space for Field Science at Sea," *Journal of the History of Biology* 47, no. 3, (August 2014), 333-362.

[37] Rozwadowski, "Small World: Forging a Scientific Maritime Culture for Oceanography," *Isis* 87, 3 (September 1996): 409-429.

CASE STUDIES

To examine the fundamentality of the ship to oceanography, I begin before oceanography had yet coalesced into a field, and certainly before ships were purpose-built to do it, in the mid-nineteenth century. My research stretches until nearly the end of the twentieth century, when oceanographic practice began a slow, still-ongoing shift away from the intimate contact with its object of study that defined an oceanographer's career for a century and a half. To cover such a broad period, I examine five case studies, chosen to trace developments in ocean-going research vessels, but also to demonstrate the development of the field, as well as shifting models of participation and patronage.

Because the development of ocean science and its reliance on ships to access the ocean is not unique to any one nation, my case studies come from several. Since I could not possibly be comprehensive, I tried to at least be broadly representative. Some of these ships are well known enough that to ignore them would have been impossible. Others are little known, but shed light on the development and employment of technology to produce knowledge about the ocean. Together, they present a broad view of the development of technology within an environment it was designed to study, even as they opened that environment as a new theater of research.

I begin in the 1840s with US navy lieutenant Matthew Fontaine Maury's studies of the ocean-atmosphere system as a means to increase the safety and reliability of commercial shipping. Maury has frequently been dismissed as a scientist. This stems in part of his status as an outsider in comparison to the scientific Lazzaroni led by Alexander Dallas Bache, Maury's rival at the US Coast Survey. His reputation took a further blow when, at the outbreak of the US Civil War, he defected to his native Virginia and joined the Confederate navy. After initial efforts to develop electrically actuated mines in Virginia waterways, Maury spent the rest of the war in England, where he was charged with acquiring commerce raiders to prey on Union shipping. Not only did his departure from Washington—and under arguably treasonable conditions—leave Bache and company unchallenged in their representations of his work as inconsequential and unscientific, but his association with Confederate commerce raiding alienated the US merchant fleet who had previously been his champions. The dismissal of Maury by historians since may stem from his relegation of astronomy, for which he was responsible in his role as superintendent of the US Naval Observatory, to a secondary concern behind his interest in ocean science.[38]

As well as falling within the paradigm of field science, the naturalists examining the ocean in the early part of this study fall within the tradition Humboldtian scientific tradition, as described by Susan Faye Cannon.[39] Maury was very conscious of his work as echoing Humboldt's own, and he played up his ties to Humboldt, with whom he corresponded and whom he eventually met. While Humboldtian science ashore have been explored with good effect, few historians have acknowledged the application of Humboldt's methods, with their emphasis on the use of instruments to gather vast quantities of data in order to drive large-scale hypotheses, to the sea. Graham Burnett's

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[38] See, for example, Nathan Reingold, *Science in Nineteenth-Century America: A Documentary History* (New York: Octagon Books, 1979), 146.

[39] Cannon, *Science in Culture: The Early Victorian Period* (New York: Dawson and Science History Publications, 1978).

work on surveyors, which he carried into an appraisal of naval surveying work and of Maury's chart project, discussed in chapter one below, is valuable work towards this end.[40]

As I describe, Maury was responsible for an effort to collect ocean science data on a vast scale, using ships as "observatories" of science, and to represent that data on charts useful to both mariners and scientists. He sent samples of Atlantic bottom material and seawater to practicing laboratory scientists for analysis, and he hypothesized about ocean biological processes and the causes of ocean circulation. That his hypotheses were frequently wrong is less important than that his conception of these processes, and of the ocean-atmosphere as a system, was global. Maury laid the groundwork for ocean research as simultaneously an international effort, a focus for national patriotism, and a tool of empire.

These last motivations were also reflected in my second case study, the British scientific circumnavigation by the HMS *Challenger* expedition, jointly sponsored by the Royal Society of London and the Admiralty in the 1870s. British naturalists and naval officers together created a model of the coalescing field of oceanography as seagoing and heroic. The *Challenger* is often treated in isolation, though, and I show that it was in fact the culmination of a partnership between naturalists and naval officers to adopt and adapt technologies to do science at sea. Though founded on a precedent of naturalists who shipped on naval vessels in order to do shore-based natural histories, the immediate

[40] Burnett, *Masters of All They Surveyed: Exploration, Geography, and a British El Dorado*. Chicago: University of Chicago Press, 2000; "Hydrographic Discipline among the Navigators: Charting an 'Empire of Commerce and Science' in the Nineteenth-Century Pacific," chapter 5 in *The Imperial Map: Cartography and the Mastery of Empire*, ed. by James R. Akerman, 185-259 (Chicago: University of Chicago Press, 2009); and "Matthew Fontaine Maury's 'Sea of Fire': Hydrography, Biogeography, and Providence in the Tropics," in *Tropical Visions in an Age of Empire*, ed. Felix Driver and Luciana Martins, 113-136 (Chicago: University of Chicago Press, 2005).

inspiration for the partnership was deep dredging work done by Swedish zoologists with access to government fisheries vessels. The Britons then collaborated on several summer cruises on older, smaller naval survey vessels, which allowed them to develop the partnership as well as the technology and techniques for working with it in deep water before launching the worldwide expedition on *Challenger*. The ship was extensively adapted to purpose before getting underway, but the adaptations continued during the trip, even as the expedition members continued to develop techniques for working and for interpreting the results of deep water sampling. The result can be viewed as both the real first intentional research vessel and as a blueprint for future ocean science research, and it laid down the expectations for those who wished to participate in such science as a career.

While *Challenger* has been characterized by Harold Burstyn as Victorian Big Science, I show that it also inspired smaller countries by providing an example of how much could be accomplished using a single ship as a platform for science.[41] It was this later lesson that inspired the requirement for ICES members to have a ship; these multiple, smaller countries working together thus had a fleet. The small science example was also evident in Prince Albert I of Monaco's use of his yachts to do oceanography, my third case study. From the 1880s to the 1920s Albert designed and outfitted a series of personal yachts as platforms for oceanography and meteorology, while simultaneously endowing institutions in Monaco and France to continue their work ashore. It would be easy to dismiss Albert's efforts as unique, the eccentric hobby of a wealthy prince. It would also be inaccurate. For one thing, yacht-board science was also pursued by Albert's

[41] Burstyn," 'Big science' in Victorian Britain: The Challenger Expedition (1872-6) and Its Report (1881-95)," in *Understanding the Oceans: A Century of Ocean Exploration*, ed. Margaret Deacon, A. L. Rice, and C. P. Summerhayes, 49-55 (London: University College London Press, 2001).

contemporaries the Briton John Murray, after his *Challenger* days, and the American Alexander Agassiz (though in both of their cases the wealth that allowed them to conduct science on personal yachts came from parlaying scientific knowledge into capitalist projects).[42] For another, Albert's work—and that of scientists he invited aboard—was recognized as serious science, even to the awarding of a 1913 Nobel Prize in Physiology or Medicine to Charles Richet, of the Faculté de Médecine de Paris, for his onboard discovery of anaphylaxis.[43] Albert thus has a legitimate claim to serving as the representative of small science. At the same time, his interest in fisheries problems and dedication to the kind of internationalism with which ICES approached science in the same period make him an example of these pursuits as well. Lastly, he provides a window on the first extensive efforts to do meteorology at sea.

In 1920s Germany, on the other hand, the scientists in my fourth case study undertook ocean research with an explicitly nationalist agenda. Backed by the Notgemeinschaft der Deutschen Wissenschaft—the Emergency Committee for German Science—they responded to their post-Great War loss of prestige and exclusion from international projects by partnering with the Weimar Navy for an extensive scientific survey of the Atlantic Ocean. Together, these organizations refitted a newly-built gunship for ocean-going research in an effort to be a world power in science if, post-Versailles Treaty, they could no longer be one militarily. Having lost their colonies with their right

[42] On Murray, see Harold L. Burtsyn, "Science Pays Off: Sir John Murray and the Christmas Island Phosphate Industry, 1886-1914," *Social Studies of Science* 5 (1975): 5-34.

[43] Albert, "Sur la troisième campagne de la *Princesse Alice II*[e]," *Comptes rendus de l'Académie des Sciences,* 28 Apr 1902; reprinted in *Résultats des campagnes scientifiques*, f. 84, 27. Richet, "Anaphylaxis," Nobel lecture, 11 Dec 1913, Nobelprize.org: The Official Website of the Nobel Prize, Nobel Media AB 2014, accessed 15 March 2017, online at http://www.nobelprize.org/nobel_prizes/medicine/laureates/1913/richet-lecture.html

to a large navy, the Germans identified the global ocean as both a promising scientific problem and a "territory" which no one could bar them from seizing. This case thus demonstrates a variation on the government-backed science model of the *Challenger*, but carried out on a relatively shoestring budget.

Here I follow Sabine Höhler, who, using Bruno Latour's depiction of the collection of data into charts as a rendition of time and space into stable but portable form, has analyzed the expedition's use of sonar to lay claim to the ocean bottom as a new territory for German expansion.[44] I expand her argument to include all of the expedition's work at sea as a nationalist project, to include reading their extensive meteorological work in the light of its potential military utility at the dawn of transatlantic aviation, a project not unlike the encouragement of civilian sailplane aviation to train a corps of pilots in the face of post-Versailles restrictions on powered aircraft, as Peter Fritsche has detailed.[45] *Meteor* thus provides a look at oceanography as a quite willing tool of politics, and demonstrates that just because a global ocean makes an apparently natural field for international endeavor, that outcome remains contingent on the agency of the human beings who study it. The oceans, and ocean science, can just as easily be leveraged for political power.

The Cold War-era American biologists in my fifth case study also saw power in the possession of ships. Pointing in the 1950s to showy Soviet vessels, they decried a “missile gap”-like deficiency in the US inventory. The ensuing push to acquire research vessels became a scramble between disciplines for independence and scientific equality.

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[44] Höhler, "Profilgewinn. Karten der Atlantischen Expedition (1925–1927) der Notgemeinschaft der Deutschen Wissenschaft." Höhler, "Depth Records and Ocean Volumes."

[45] Fritzsche, *A Nation of Fliers: German Aviation and the Popular Imagination* (Cambridge, MA: Harvard University Press, 1992), especially ch 3, "Gliding and the Revival of Nationalism," 103-131.

American biologists from various ocean science disciplines worked together to define themselves as oceanographers, for whom ships were essential to purpose. Yet once they got ships, like the Scripps Institution of Oceanography's Research Vessel *Alpha Helix*, which I examine here, they limited their work at sea, often using the ship as a laboratory that could be "parked" in remote littoral locations. They embraced the tradition of heroic shipboard science, though, and argued for its importance to graduate training and thus to the coming-of-age of the next generation of scientists.

It is the nature of case studies to exclude and ignore in order to represent. I have attempted to cover the range of ocean sciences, as well as at least a modest breadth of the Western countries conducting them. There are, of course, other ships that could have taken the place of each of these. Others still could supplement them. The vessels I have chosen represent a variety of sizes, patronage models, and scientific disciplines, and thus I ask them to stand in for other possibilities.

While the merits of including or excluding any particular ship or groups of ships might of course be debated, historians of ocean science will notice at least three major omissions here. Most notable, perhaps, is the omission implicit in my categorization of these ships as Western. Collectively the ships examined in the chapters that follow conducted research in every sea of the global ocean, but they represent the patronage and scientific engagement of only a handful of Western nations. Asia, South America, and Africa are represented only as ports of call, though a handful of their scientists appear in passing. An exploration of the efforts of non-Western nations to conduct science at sea would greatly enrich our picture of its development.

Within the West, I have not included a Scandinavian vessel, despite those countries' significant role in the development of the ocean sciences during this period. Still, Scandinavian science is well represented here, with oceanographer Johan Hjort's epigram at the start of this introduction, zoologists Michael Sars' and Georg Sars' inspiration of the British work in chapter 2, botanist Hanna Maria Resvoll-Holmsen's notable participation in Albert's Arctic expedition in chapter 3, oceanographer Walfrid Ekman's presence onboard the preliminary *Meteor* voyage in chapter 4, and Per Scholander's centrality to chapter 5. That said, an analysis of their efforts at home—on *Fram* or *Michael Sars*, perhaps—would no doubt be richly rewarded.

I have also, as I acknowledged above, given short shrift to fisheries science. Perhaps the most obvious candidate here would be the US Fish Commission Ship *Albatross*, which instead I mention only in passing. Though *Albatross* certainly has a claim to importance as apparently the first ship designed from the keel up for ocean research, I declined to include it in the interests of not skewing too American. Prince Albert's interest in fisheries' problems must suffice, though *Albatross* and its siblings are overdue for a modern examination.

Together, these case studies trace the development of oceanography over the course of the nineteenth and twentieth centuries and the opening of the sea as a theater of science. Oceanography was a foreign neologism in the 1850s, when Matthew Fontaine Maury started using ships to feel out the contours of the Atlantic, but did so from his desk in Washington, as described in chapter 1, below. Over the course of the next century the term's use to define the boundaries of ocean science solidified, even as an increasing range of scientific activity was subsumed, or occasionally squeezed by pure force of will, within them. At the beginning of the period, a definition of "oceanography" was limited because so little was known of the oceans as an arena for science that it was not yet completely clear, except perhaps in broad theory, what all their study might entail. By the end of the period, oceanography as a field or discipline and oceanographers as practitioners were no easier to define, in part because of the terms' very plasticity.[46] Witness the efforts of the American biologists in chapter 5, below, to include their marine biology and physiology and even coastal botany within oceanography's purview. These case studies demonstrate scientists' employment of ships to access the depths. No matter how they were defining their science, that employment increasingly defined their scientific activities over the course of the period, and thus increasingly defined what it meant to be an oceanographer. By the mid-twentieth century, then, the amorphous field of oceanography had at least this one defining constant: Oceanographers were scientists who went to sea.[47] This dissertation examines how that happened.

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[46] Historian of oceanography Eric L. Mills had noted that oceanography "does not lend itself to neat formulations, scientific or historical," "The History of Oceanography: An Introduction," *Earth Sciences History* 12, no. 1 (1993): 1.

[47] I thank Helen Rozwadowski for this succinct formulation, in an early conversation that led to this study.

CHAPTER 1: Matthew Fontaine Maury's Floating Observatories

Every ship that navigates the high seas, with these charts and blank abstract logs on board, may henceforth be regarded as a floating observatory, a temple of science.

-- Matthew Fontaine Maury[1]

On 3 March 1849, the US Congress directed the secretary of the navy "to detail three suitable vessels . . . in testing new routes and perfecting the discoveries made by Lieutenant Maury in the course of his investigations of the winds and currents of the ocean."[2] Matthew Fontaine Maury had been head of the US Navy's Depot of Charts and Instruments since 1842 and would be for another twelve years, until his resignation in 1861 on the eve of the Civil War. Over the last seven years, Maury had transformed the depot from a repository of charts and instruments to a place of knowledge production. He was well known to Congress and to the public for his development there of the Wind & Current charts and Sailing Directions. These ships were intended to achieve a culmination of those research efforts.

Though produced by the navy and distributed free to merchant mariners for the benefit of American commerce, the charts and the knowledge they embodied were not intended solely for navigation, dear as that subject was to Maury's heart. He expressed early in their development a second purpose for these visual technologies: as a tool of science. Nor were the charts the only technologies he reimagined, and often redesigned, as scientific instruments. This chapter examines Maury's efforts to study the oceans via the development of innovative charts and the use of ships to test them, as well as with a

[1] Maury, *The Physical Geography of the Sea*, ed. John Leighly. (Cambridge, MA: Belknap Press of Harvard University Press, 1963), 6.

[2] Naval Appropriations Act FY 1850, US Statutes at Large, 30 Cong. 2 sess., Ch 103, 9 St. 374.

variety of other technological means of producing knowledge about a remote environment. Because, as a naval officer, Maury was intimately familiar with the difficulty of accessing the ocean depths, he emphasized technologies of investigation and of representation, using and modifying them in innovative ways to achieve his dual goals: a more thorough understanding of the structure and processes of the ocean-atmosphere system, and a representation of the data thus gathered in a format useful to both the working scientist and the sea-going public. In the process he made both depot and ship into places for doing science, and habituated both government and public to the idea that science on a global scale was inherently useful, requiring and deserving government support.

At the same time, Maury was involved in the efforts of both scientists and naval officers in the United States to professionalize their disciplines in the mid-nineteenth century.[3] In deploying ships for the purposes of science, corresponding with noted scientific practitioners, participating in scientific societies, and publishing in the scientific press, Maury assisted in efforts to establish professional scientific networks and to expand the realms accessible to science. At the same time, he argued for science as a legitimate and desirable activity for naval officers, for the establishment of a formal and scientific system of naval education, and for the inclusion of naval officers in the professions. In the long term, both of these projects succeeded, as science became increasingly professionalized, the oceans became a site for scientific inquiry, and the navy established the United States Naval Academy in Annapolis in 1845. Yet despite these successes, and Maury's integral role in both projects, his involvement in each canceled the other out in the

[3] I have argued this point elsewhere. See Penelope K. Hardy, "Matthew Fontaine Maury: Scientist," *International Journal of Maritime History* 28, no. 2 (May 2016): 402-410.

eyes of his contemporaries, leading his contemporaries in the navy to dismiss him as too interested in scientific advancement to be a serious naval officer, while scientists of his era and historians of science since tended to dismiss him as a mere technician.[4] This reflects not only a view of mid-nineteenth-century American science that requires reappraisal, but also a somewhat dismissive view of technology as applied science.

In the case of the ocean sciences, in particular, Maury's work began a long tradition of maritime professionals' involvement in the projects of oceanography, required for the successful deployment and creative adaptation of old technologies and the development of new. Examining Maury as a scientist and the development and integration of technology into his practice provides a window onto a pattern of scientific practice whose echoes propagated forward through the scientific cruises of the later nineteenth century and into the twentieth. Maury's scientific endeavors—and indeed the ocean sciences as a whole—also constitute a case study in the reevaluation of technology's role in "doing" science more broadly.

TRANSFORMING THE DEPOT OF CHARTS AND INSTRUMENTS

When Lieutenant Maury took command of the US Navy Depot of Charts and Instruments in 1842, he assumed an array of responsibilities both wide-ranging and ill-defined. The need for a depot had been recognized in about 1830 to fill a hole in the navy supply chain; previously, US naval vessels were fitted out unevenly through naval agents who purchased charts and instruments on the open market, mostly from foreign

[4] Nathan Reingold, *Science in Nineteenth-Century America: A Documentary History* (New York: Octagon Books, 1979), 146.

sources.[5] With no pre-purchase testing, their quality and reliability varied unpredictably and—since ships and lives depended on them—dangerously. A ship lucky enough to be well-supplied with charts and instruments when it departed on cruise would not see that luck repeated; post-cruise, everything was stored haphazardly, with no provision for maintenance. "As a necessary consequence," the House Committee on Naval Affairs later noted, "the same set of instruments rarely went to sea two cruises."[6]

In response to these deficiencies, the secretary of the navy established the depot in 1830 as a central repository, proving ground, and maintenance facility for instruments, with the responsibility for charts added the following year. From the beginning, depot superintendents argued the need for a basic astronomical observatory to set and test the accuracy of ships' chronometers. Neither navy nor Congress responded officially until 1842, but early superintendents industriously set up the facilities they needed; Lt. Charles Wilkes went so far as to house the depot in his own home. When he left to command the US Exploring Expedition (USExEx), he rented the facilities to the navy. By that point, finally convinced of its necessity, Congress allocated $25,000 for instruments and books and to build an observatory in the District of Columbia. Maury moved the depot into this new building in 1844, adding Superintendent of the Naval Observatory to his title.

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[5] Gustavus A. Weber, *The Hydrographic Office: Its History, Activities and Organization*, Institute for Government Research, Service Monographs of the United States Government, no. 42 (Baltimore: Johns Hopkins Press, 1926), 8-24; Weber, *The Naval Observatory: Its History, Activities and Organization*, Institute for Government Research, Service Monographs of the United States Government, no. 39 (Baltimore: Johns Hopkins Press, 1926; Stephen J. Dick, *Sky and Ocean Joined: The U.S. Naval Observatory, 1830-2000* (Cambridge: Cambridge University Press, 2003); Dick, "Centralizing Navigational Technology in America: The U.S. Navy's Depot of Charts and Instruments, 1830-1842," *Technology and Culture* 33, no. 3 (July 1992): 467-509.

[6] 27 Cong. 2 sess., H. rep. 449.

A native Virginian, the young Maury had attended a preparatory academy in Tennessee, where the principal recommended West Point as a place to pursue his interests in math and science.[7] His father's refusal to consider this option, plus the untimely death of his much-older brother, a navy lieutenant who had brought Matthew up on stories of adventure, led the young man to apply for a midshipman's warrant behind his father's back. During the first several years of his service, in addition to learning the nautical and navigational skills necessary for his chosen career, Maury reportedly taught himself spherical trigonometry and read a Spanish navigation manual with a dictionary in hand to learn that language. He was disappointed with what little "formal" education was available to midshipmen: shipboard schoolmasters who lacked materials and/or motivation to teach and in-port training schools intended to prepare for the midshipman's exam. Maury received permission to skip the latter and study independently for the test.

Post-exam, preparing for the responsibilities of his new position as sailing master in USS *Falmouth*, Passed-Midshipman Maury sought wind and current information for the daunting voyage around Cape Horn and found nothing. Upon his return, he made his first effort to remedy this lack with an article relating his own experience, which was published in Benjamin Silliman's *American Journal of Science and the Arts* in 1834, along with a second article by Maury, "Plan of an Instrument for Finding the True Lunar Distance."[8] These small successes must have inspired Maury to address the lack of education he

[7] The summary which follows relies mostly on Frances Leigh Williams, *Matthew Fontaine Maury, Scientist of the Sea* (New Brunswick, N J: Rutgers University Press, 1963), and Charles Lee Lewis, *Matthew Fontaine Maury: The Pathfinder of the Seas* (Annapolis: United States Naval Institute, 1927).

[8] Maury, "Art. 5--on the Navigation of Cape Horn," *American Journal of Science and Arts* 26, no. 1 (July 1834): 54-63; Maury, "Art. 6--Plan of an Instrument for Finding the True Lunar Distance," *American Journal of Science and Arts* 26, no. 1 (July 1834): 63-65.

perceived in the fleet, though a long wait for his next assignment also gave him time to do so. He wrote a manual that would teach the mathematical theory behind navigation, rather than just the necessary skills. It was published in 1836, while Maury was still a passed midshipman, and eventually adopted as a textbook by the navy.[9]

INSCRIBING THE OCEANS

Maury's tenure at the depot began as an extension of his predecessors' efforts to corral, calibrate, and control shipboard instruments. Despite the twelve years' effort, the navy faced continued instrumentation problems. Maury spilled much ink and the sweat of many lieutenants chasing down old instruments and getting receipts for new ones, whether because captains treated them lackadaisically—a cardinal sin in Maury's eyes—because they coveted more of them than the now-centralized control allotted, or because they did not trust the issued instruments.[10] The problems were not all with end users; the depot also dealt with suppliers. Maury corresponded with artisans upset that a period of trial before purchase was now required on their instruments, which delayed payment and, they complained, implicitly questioned their craftsmanship. Inventors, usually amateurs, wrote with ideas for new instruments or improvements on old ones; Maury offered patient critique of their suggestions.[11] By 1845 Maury was able to report in his annual budget request, "The circumstance of having the instruments for the navy purchased by the

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[9] Maury, *A New Theoretical and Practical Treatise on Navigation. . . .* (Philadelphia: Key and Biddle, 1836).

[10] For example, Maury to Commander W. M. Armstrong, US Sloop *Marion*, Norfolk, 7 Sep 1842; Volume 1, 16 July 1842 to 31 July 1845 (Vol. 1); Entry 1: Letters Sent (LS); Records of the U. S. Naval Observatory, Record Group 78 (RG 78); National Archives Building, Washington, DC (NAB); and ibid, 4 Nov 1842.

[11] For example, Maury to F[rancis] B[arber] Ogden, US Consul, Bristol, 15 March 1851; Volume 6, 16 September 1850 to 26 May 1851 (Vol. 6); LS; RG 78; NAB.

quantity after careful trial & proof . . . has contributed in no small degree to lessen their cost, and to secure for the navy instruments of a much better quality."[12]

The problems Maury saw with chart procurement were even more fundamental, and more dangerous. He was not the first to note that Americans printed no charts of their own. An 1828 article in the *New York Mirror* glossed it as a prick at the nation's honor: "When our naval commanders and hardy tars have achieved a victory on the deep, they have to seek our harbours, and conduct their prizes to port, by tables and charts furnished, perhaps, by the very people whom they have vanquished."[13] With the burning of Washington at British hands still in living memory, Maury no doubt had a darker worry when he noted,

> We are dependent not only upon the English and French Admiralty for the charts and information by which our vessels navigate the more distant seas, but of our own waters. As yet an American man-of-war cannot enter the Capes of Virginia, or approach this city [Washington], the Capital of the Union, without applying to the Hydrographical Office of England for a chart on which to shape her course. The only charts of the Northern Lakes that we have are procured from the English and thro' the courtesy of the Admiralty Office. [14]

Aside from the security issues, foreign sourcing of charts of domestic waters also led to a logistical nightmare. Orders placed overseas, whether through agents in New York or direct from London or Paris, were not only subject to shipping delays, but also dependent on the reliability and currency of catalogs and the responsiveness of suppliers. Maury's exasperation was clear when he wrote his London supplier in April 1843, "The

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[12] Maury to Commodore William M. Crane, Chief of the Bureau of Ordnance and Hydrography, Washington, DC, 20 October 1845; Volume 2, 6 August 1845 to 7 April 1848 (Vol. 2); LS; RG 78; NAB.

[13] Jeremiah N. Reynolds, quoted in the *New York Mirror*, 4 Oct 1828. Cited in William P. Leeman, *The Long Road to Annapolis: The Founding of the Naval Academy and the Emerging Early Republic* (Chapel Hill: University of North Carolina Press, 2010), 97.

[14] Maury to Crane, 20 October 1845; Vol. 2; LS; RG 78; NAB.

delay in the execution of the Order of 19th April [1842] has caused much inconvenience and dissatisfaction." Yet the lack of alternatives forced him to continue by adding more charts to the order![15] When charts did arrive in the US, he must ensure they would clear customs in a timely manner and duty free.[16] Even clearance of all those hurdles did not guarantee success, as in a case he complained of to Commodore Crane, head of the newly-formed Bureau of Ordnance and Hydrography and Maury's immediate superior: "The charts sent by Commo Kennedy, have been examined. A portion of them are out of date, several being more than 120 years old."[17] No wonder then, that after a year at the depot Maury requested permission "to construct a general chart of the Atlantic, from the best sources of information within my reach" and to maintain a master copy so "correction of every ascertained error may be made as soon as discovered."[18]

But given Maury's background, he believed charts could provide more than the usual hydrographic info. The idea, he reported later, first arose from the pile of moldering log books he found in the depot office when he arrived. While the navy required these hand-written, day-by-day accounts of shipboard activity to be sent to the depot after each cruise, it did not specify what the depot was supposed to do with them, besides storing them as official records. So Maury's predecessors had done little more than store them, in their hundreds. Maury realized these logs contained the recorded experience of navigators that he had coveted as sailing master in *Falmouth*. He had his junior officers

[15] Maury to R. B. Bate, Poulty London, 15 April 1843; Vol. 1; LS; RG 78; NAB.
[16] Maury to Collector at New York, 15 August 1843; Vol. 1; LS; RG 78; NAB.
[17] Maury to Crane, 16 March 1843; Vol. 1; LS; RG 78; NAB.
[18] Maury to Crane, 25 September 1843; Vol. 1; LS; RG 78; NAB.

comb them for details of wind, current, and any other available data.[19] By representing the accumulated information graphically, Maury envisioned a chart on which "the experiences of a thousand navigators" would guide the neophyte "as though he himself had already been that way a thousand times before."[20]

As taken as Maury was with the idea's potential, the reality fell short on several fronts. For one, the newfound vein of information was soon mined out. In exhausting its potential, Maury and his officers discovered lacunae in the data. No standard set of information was required to be documented in the log, beyond the most basic record of a ship's operations. Some captains recorded winds and currents frequently; others did not. Some recorded it without clear reference to the ship's position, making it useless for Maury's purposes. Some recorded extra information—such as water temperatures and weather observations—which Maury believed would be useful if only it could be collected on the same scale as the wind and current information.

Believing he was on to something important, he began communicating with captains directly, providing them a data wish list, including:

> The tracks of as many vessels as can be obtained with dates.
> The prevailing direction and force of the wind for each day of the passage.
> Temperature of air and water, with hight [sic] of Barometer.
> Storms their duration and direction. Limits of Gulf Stream force and set of currents
> Ice bergs their place and date when seen.
> Accounts of phenomena of all sorts, with remarks and observations illustrating the advantages of any particular route from one port to another.

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[19] D. Graham Burnett, "Hydrographic Discipline among the Navigators: Charting an 'Empire of Commerce and Science' in the Nineteenth-Century Pacific," ch 5 in *The Imperial Map: Cartography and the Mastery of Empire*, ed. James R. Akerman (Chicago: University of Chicago Press, 2009), 194.

[20] Maury, *The Physical Geography of the Sea,* entirely new ed. (New York, 1856), vii. All subsequent citations refer to this edition unless otherwise noted.

Fields of sea weeds their position – Limits of the Sargossa [sic] Sea.[21]

He also asked them to report any errors found on published charts, especially vigias—shoals charted on slender evidence—many of which he believed did not actually exist. While initially he asked his fellow officers to gather data as "a great favor" and hoped his assurance that the data was very useful would be sufficient to motivate their cooperation, that approach ensured neither the quantity nor the consistent quality of data he wanted.[22] To standardize the data, Maury devised an "abstract log," a blank form which would prompt the observer to record specific kinds of data at specific times. This log, which evolved into a set of forms in slightly different format for different users, was itself a technology of data collection and standardization. To broaden interest in his effort, he had a paper read at the 10 July 1843 meeting of the National Institute for the Promotion of Science—of which many prominent citizens in the capital were members, including numerous members of Congress and high-ranking military officers. In it, Maury proposed a plan to furnish blank logs to all American vessels to collect navigation information.[23] To reach the broader public, Maury published a similar article in August in the *Southern Literary Messenger* on "Blank Charts on Board Public Cruisers," by which of course he meant US naval vessels.[24]

By October 1843, he had convinced Commodore Crane of his project's value, and he wrote up a few pages of "Suggestions for the Attention for the Home Squadron,"

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[21] Maury to Captain F. H. Gregory, USN, USS *North Carolina*, New York, 29 August 1843; Vol. 1; LS; RG 78; NAB.

[22] Maury to Gregory, 29 August 1843; Vol. 1; LS; RG 78; NAB.

[23] *Proceedings of the National Institute for the Promotion of Science*, Bulletin no. 3, 308. For membership in the National Institute, see Ralph S. Bates, *Scientific Societies in the United States*, 3rd ed. (Cambridge, MA: M. I. T. Press, 1965), 69.

[24] Maury, "Blank Charts on Board Public Cruisers," *Southern Literary Messenger* IX, no. 8 (August 1843), 458.

detailing not only what data he wanted, but which instruments already onboard their vessels could be used to gather it, where and how best to set them up, and how often to take observations.[25] The home squadron, while ideal for investigating the Gulf Stream and waters of the Atlantic, operated in only a limited area; Maury's vision encompassed the world ocean. At the 1844 annual meeting of the Association of American Geologists and Naturalists, after Maury read a paper on currents and geology accompanied by a chart of the north Atlantic, geologist Henry Darwin Rogers proposed the formation of a committee to draw up observation instructions, with the hope that the secretary of the navy would then issue them to naval commanders.[26] In November the committee—clearly via Maury's pen—petitioned the secretary to instruct US naval vessels operating worldwide "to make & record observations . . . which the nature of the service upon which they may be engaged, will admit."[27]

Alas for Maury, his fellow officers were not universally enchanted by the possibilities of his project. He was able to report as early as October 1845 that his lieutenants were at work compiling a chart of the Atlantic from the materials on hand; he hoped to have it ready for publication by the end of the year. But he complained that many more officers ignored his request for data than complied.[28] Even had they all responded, the six navy squadrons then extant operated in very specific locations; while he

[25] "Suggestions for the Attention for the Home Squadron," 3 October 1843; Vol. 1; LS; RG 78; NAB.

[26] Henry Darwin Rogers, *Address Delivered at the Meeting of the Association of American Geologists and Naturalists, Held in Washington, May, 1844, with an abstract of the Proceedings at Their Meeting* (New York: Wiley & Putnam, 1844), 40.

[27] Maury, H[enry] D[arwin] Rogers, [Edward] Hitchcock, [James Pollard] Espy, [William Charles] Redfield, [James Dwight] Dana, and [Joseph P.] Couthouy to [John Y. Mason,] secretary of the navy, 11 November 1844; Vol. 1; LS; RG 78; NAB.

[28] Maury to Crane, 25 October 1845; Vol. 2; LS; RG 78; NAB.

could piece together a chart of the Atlantic, even that was devoid of data on routes not frequented by naval vessels.[29] To cover the rest of the ocean he would need to cast his net a bit wider.

Representative Stephen Mallory, chair of the House naval affairs committee, had noted as early as 1842 the existence of "a great mass of . . . information locked up in the memories of our whalers and Indiamen," which he imagined them quite willing to share if they only knew where to send it. As it was, it was only ever passed onto to members of their immediate crew. Mallory had in mind the discoveries of new shoals and reefs, making these merchantmen the source of many of Maury's vigias, but the idea was there: If the depot could once tap it, "How useful the knowledge would be to other navigators!"[30] To get at this information, Maury again began by recruiting individual captains, and he wrote at the beginning of 1848 to the hydrographic bureau chief, now Commodore Lewis Warrington, suggesting a wholesale push to ask merchants for data. Maury provided an example of the service he expected the gathered data to provide: Mail packets from Le Havre to New York took on average nine days longer than those travelling from Liverpool to New York, despite their route covering only 100 more miles. Were more known of the winds and currents, the cause of this delay might be apparent—and, he implied, avoidable. His plan then was to furnish merchants with his blank forms; if they returned them filled with data at the end of their voyage, they would be furnished with a copy of his wind and current chart.[31]

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[29] Kenneth J. Hagan, *This People's Navy: The Making of American Sea Power* (New York: Free Press, 1991): 142-157.

[30] 27 Cong. 2 sess., H. rep. 449.

[31] Maury to Warrington, Washington, DC, 16 January 1848; Vol. 2; LS; RG 78; NAB.

The potential of the new plan excited Maury. As he wrote to one of his lieutenants, "Instead of searching through cart loads of manuscripts and dusty old log-books, kept in years gone by, without system, and with little or no regard to the facts which I wish to obtain from them, I now have the prospect of having, as co laborers, a thousand or more vessels every year, each engaged in collecting exactly the information required, so that it will come to my hands precisely in the form and shape in which it is desired."[32] Still, the dusty search had paid off in the form of enough information to assemble his first chart, even if his predicted timeline had been overly optimistic. In July 1847 he sent his frequent correspondent Robert Walsh, US consul in Paris, a few copies of the first sheet of his wind and current chart.[33] By November the other seven sheets of the Atlantic were in press, and Maury sent copies of the first to John Quincy Adams.[34]

The charts differed from previous ones because instead of simply displaying the ocean and land—the setting of a voyage—they displayed as well the voyages of each ship that had contributed to the project. This provided, as Maury had long desired, the accumulated experience of those who had travelled that path before to both neophyte and veteran navigator. As Maury explained,

> The manner in which this is to be accomplished, may be understood by an examination of sheet N°. 2. South Atlantic where the tracks are laid down in colours according to the four seasons of the year—and by continuous, broken or dotted lines according to the month. If the track be an unbroken line, it represents the first month of the season— Thus if the track be black it was made in December; if green, in March; if red in June or if blue, in September. So too of the broken lines which represent January, April, July or October of the second month of the season. The

[32] Maury to J. C. Walsh, 24 January 1848; Vol. 2; LS; RG 78; NAB.
[33] Maury to Robert Walsh, US Consul, Paris, 9 July 1847; Vol. 2; LS; RG 78; NAB.
[34] Maury to Adams, 17 November 1847; Vol. 2; LS; RG 78; NAB.

dotted line represents the third month of the season—February, if black; May, if green; August, if red, &, November if blue.[35]

Along those track lines, small, comet-shaped graphics indicated the direction and force of winds encountered, as well as their consistency. Currents were marked with a number indicating knots alongside an arrow indicating direction. With the charts, Maury published a volume of explanations and sailing directions—initially a slim pamphlet, but of increasing heft with each new edition over the following years. These both explained how to read the charts and, later, analyzed specific example tracks sent in by Maury's corresponding observers.

However, to convince sailors who might participate that the data had worth would take practical results. One of the first routes for which Maury felt he had enough data to make prescriptive suggestions was that from the US to Rio de Janeiro. This route was so frequently travelled because most of it, from the US to the tip of Brazil at Cape St. Roque (Cabo de São Roque), was taken by every American ship headed south for any reason, whether to Rio or to round either Cape to the Indian or Pacific Ocean. The route was thus both heavily documented, giving Maury much to work with, and of extreme interest to seamen. After analyzing his collected data, Maury believed the strong currents around St. Roque, which ships routinely took a circuitous or zig-zag course to avoid, did not actually exist. He suggested instead a straight-line course.

To trust a course charted at a desk ashore via an accumulation of numbers over the traditional knowledge learned at sea was to make a leap of faith. The first ship willing to take it was the *W. H. D. C. Wright*, a bark out of Baltimore. Following Maury's

[35] Maury to Warrington, September 1848; Volume 3, 28 February 1848 to 5 February 1849 (Vol. 3); LS; RG 78; NAB.

directions, Captain Jackson in the *Wright* made Rio from the Virginia Capes in thirty eight days, a seventeen-day improvement over the previous average of fifty five; his thirty-seven day return trip proved it was no fluke.[36] News of the voyage spread quickly, winning sailors to Maury's cause. In February 1848, in reply to Maury's January request, Commodore Warrington permitted him to distribute copies of the chart to the master of every ship who agreed to collect data on Maury's abstract logs and submit them to the depot upon return to the US.[37] Maury reported to Warrington six months later that several thousand copies of the first chart series had been distributed to ships' masters willing to keep and submit logs, "and at this moment there are thousands of American vessels engaged in all parts of the world in making the requisite observations for this work. Never before has such a corps of observers been seen." As a result, charts of the Atlantic, Pacific, and Indian Oceans were already in preparation.[38]

In addition to this greater geographic coverage, Maury began to plan charts displaying more kinds of information. The original set of charts with their collected tracks—the Track Charts—would be known as Series A. They were followed by Trade Wind Charts (Series B); Pilot Charts, which showed prevailing winds in various seasons (Series C); Thermal Charts (Series D); Storm and Rain Charts (Series E); and Whale Charts (Series F), which promised whalers a statistical database from which to make hunting decisions and biologists a census of sightings and behavior.[39]

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[36] Maury, *Explanations and Sailing Directions to Accompany the Wind and Current Charts,* 4th ed. (1852), 41-42, cited in Williams, *MFM*, 180.

[37] Maury to Warrington, September 1848; Vol. 3; LS; RG 78; NAB.

[38] Maury to Warrington, September 1848; Vol. 3; LS; RG 78; NAB.

[39] These chart series have been enumerated by the American Geographical Society Library at the University of Wisconsin Milwaukee, "Matthew Fontaine MAURY Ocean Charts at AGS Library," updated 18 May 2012, http://uwm.edu/libraries/wp-content/uploads/sites/59/2014/06/maury.pdf

TURNING NAVIGATORS INTO SCIENTISTS

Aboard every properly outfitted ship, and certainly aboard naval vessels for whose outfitting Maury's office bore responsibility, the basic tools of navigation provided a means of both accurately fixing one's position and of gathering observational data about the ocean and atmosphere—if the ship's officers would use them properly. Maury's "Suggestions for the Attention for the Home Squadron" included not just the suggestion to use astronomical bearings to better determine the force and set of currents, but detailed instruction on which instrument to use ("the Prismatic azimuth compass") and how and where to mount it for best results (on its own tripod "ab aft the binnacle and as near the centre of attraction from the surrounding guns and other ferruginous materials as possible. . . . Each foot of the tripod should have its mark on the deck, on which it should always be placed.")[40] Indeed, his response to an inquiry from the British Magnetic Committee in 1845 urged continued support for the science of magnetism because the fruits of "enduring, patient, laborious investigation concerning the trembling subtileties [sic] of the 'Needle'" would eventually be "reaped and enjoyed by the Mariner at sea." In its current state, he warned, the compass—the most important navigational instrument aboard—was in many ways the least understood, and he enumerated the shipwrecks and widows made annually by its false advice.[41] He frequently urged mariners to pay attention to the thermometer and barometer as well.

Yet the usefulness of these standard instruments of navigation was not limited in Maury's mind to improvements in navigational practice. Prussian scientist Alexander

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40 "Suggestions for the Attention for the Home Squadron," 3 October 1843; Vol. 1; LS; RG 78; NAB.

41 Maury to Lieut Col [Edward] Sabine, Woolwich, 22 February 1845; Vol. 1; LS; RG 78; NAB.

von Humboldt actually suggested Maury's results were sufficiently novel to constitute a new science, which Humboldt called the physical geography of the sea. Maury was happy to adopt the phrase as the title of a book intended to communicate his results and their implications to an audience beyond the maritime community.[42] Invoking the scientist, who was among other things famous for the quantity of instruments he carried into the field, marked Maury and his observers as working within the then-dominant paradigm for reliable, measurement-based geographical science.[43] Indeed, Maury wanted to study the extreme conditions of the sea, more remote than any Humboldtian mountaintop, with "[e]very ship that navigates the high seas [serving as] . . . a floating observatory, a temple of science."[44] Maury understood that the primary roles of his floating observatories were as ships of war and of commerce, and that his backers were more committed to those roles, so he emphasized how little his prescribed plan of observations would impact their operations. A letter to Humboldt at the beginning of 1848 displays Maury's usual mix of practical justification and scientific vision:

> The men of war of all nations are already provided with all the instruments, facilities & means for conducting the proposed system of observations. Currents, winds & drift, variation of the Compass, temperature of the water at and below the surface–the habitats of animalculae, fish, & creeping things, the meteorology of the ocean—will constitute the main objects of attention. Such observations you may observe will but tend to the more safe & certain navigation of the vessels on board of which they are made, & can be conveniently attended to by the Master, or others having charge of the navigation. [45]

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[42] Maury, *Physical Geography*, x-xi.

[43] D. Graham Burnett, *Masters of All They Surveyed: Exploration, Geography, and a British El Dorado* (Chicago: University of Chicago Press, 2000), 15.

[44] Maury, *Physical Geography*, xi; Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (New York: Dawson and Science History Publications, 1978), 78, 74.

[45] Maury to [Humboldt via] Robert Walsh, 30 December 1847; Vol. 2; LS; RG 78; NAB (underline in the original).

Clearly wind and current mattered to the navigator; the habitats of "animalculae" might conceivably be relevant only at the end of a long chain of purely scientific investigation. To officers he knew, Maury suggested scientific problems of this sort which he thought they could address based on their route and schedules, making every ship a possible observatory of opportunity. "Will you notice particularly when in the trade wind regions the direction of the upper stratum of clouds," he asked one lieutenant. "It becomes now a matter of much interest to know how high up that current of wind is & what velocity, which flows from the equatorial calms in the upper regions of the air back towards the sources of the trades."[46] Similarly, he continually reminded mariners of the other uses to which their instruments and their data could be put. He instructed Lt. William Rodgers Taylor on the *Albany* to estimate the velocity of clouds. To do so, he suggested tracking their angular altitude above the horizon at intervals of a few minutes using a sextant, from which the lieutenant could calculate height and then velocity.[47]

Information on the behavior of winds far aloft was not of any immediate use to the lieutenant, nor to Maury's accumulation of navigational advice. Instead, Maury wanted it as part of a more ambitious study. He perceived the ocean and atmosphere as a united system, one whose physical laws could be understood. He believed that if he could gather information using this corps of observers already deployed, using tools already in place, it could lead to a better understanding of the physical world. He said explicitly he had "enlisted" these sailors to do science, specifically the physical geography of the sea, and "[u]nder this term will be included a philosophical account of the winds and currents of the

[46] Maury to Lt. William Rodgers Taylor, Ship *Albany*, 4 Feb 1857; Vol. 6; LS; RG 78; NAB.
[47] Maury to Taylor, 4 Feb 1857; Vol. 6; LS; RG 78; NAB.

sea; of the circulation of the atmosphere and ocean; of the temperature and depth of the sea; of the wonders that lie hidden in its depths; and of the phenomena that display themselves as its surface."[48]

While he consistently thanked his contributors, well aware that they were volunteers, Maury also treated them as professionals. He was not hesitant to correct any who failed to provide all the data he wished for, or to ask for further information.[49] Nor was he stingy with praise for officers who went beyond his basic abstract requests, even using their contributions to shame others who wasted good opportunity. After praising the officers of the *Albany* for their "exceedingly valuable and very interesting" deep sea soundings, Maury contrasted their performance with that of the *Saratoga*: "She spend $2700 for sounding twine, her's [sic] was three of yours laid up, and she went to Rio without making a single sounding."[50] Maury promised to publish Taylor's diary, and when he did so publicly called out Captain Walker of the *Saratoga* in the same publication.[51]

LOBBYING FOR SCIENCE AT SEA

Despite Maury's frequent correspondence with former president Adams, diplomats, legislators, and the upper echelons of navy leadership, the ships Congress allotted in 1849 for "testing new routes and perfecting the discoveries made by Lieutenant

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[48] Maury, *Physical Geography*, xiv.

[49] For example, Maury to J. W. Norton, Ship *Navy*, New Bedford, MA, 2 April 1851; Vol. 6; LS; RG 78; NAB.

[50] Maury to Taylor, 4 Feb 1857; Vol. 6; LS; RG 78; NAB.

[51] *Lieut. Maury's Investigations of the Winds and Currents of the Sea (From the Appendix to the Washington Astronomical Observations for 1846* (Washington, DC, 1851), 31-34.

Maury" had not been easy to come by.[52] The idea had first been advanced by a coalition of Boston shipowners, who offered to gather $50,000 to engage a ship to test his new route suggestions, but Maury insisted the work belonged onboard a naval vessel. While this may in part have been because the disciplined operation of a ship of war would ensure strict adherence to Maury's program for the voyage, it was also because Maury hoped to use the ships for considerably more "perfecting the discoveries" than the "testing new routes" the merchants had in mind.[53] Though set on having a navy ship, Maury again approached the problem through a public campaign rather than believing any direct appeal to his chain-of-command would be effective. Apparently with his commodore's blessing, he suggested the shipowners petition the secretary of the navy; when nothing came of it, they tried again with the Senate.[54] This latter effort bore the fruit in the Naval Appropriations Bill.

While Maury was never able to make good on the promise of three vessels, he was afforded the use of two for cruises under his direction.[55] The first of these was the former revenue cutter *Taney*, commanded by Lt. J. C. Walsh, a junior officer from Maury's observatory and depot staff. While the ship was fitting out in New York, Maury and Walsh corresponded frequently and before its departure Maury wrote detailed instructions

[52] Naval Appropriations Act FY 1850, US Statutes at Large, 30 Cong. 2 sess., Ch 103, 9 St. 374.

[53] Burnett makes the discipline argument in his "Hydrographic Discipline," 185-259; Edward Leon Towle, "Science, Commerce and the Navy on the Seafaring Frontier (1842-1861) – The Role of Lieutenant M. F. Maury and the U. S. Naval Hydrographic Office in Naval Exploration, Commercial Expansion, and Oceanography before the Civil War" (Ph.D. diss., University of Rochester, 1966), ProQuest (6606873), 272-3.

[54] Maury to Forbes, 18 Feb 48; Vol. 2; LS; RG 78; NAB. Ibid., 8 Jan 49; Vol. 3.

[55] A third vessel, the *Arctic*, made soundings across the Atlantic in 1856 in anticipation of the laying of the first Transatlantic cable, but the ship was not under Maury's command, and he contested the validity of its soundings and thus the interpretation of its results. For a summary of the incident, see John Grady, *Matthew Fontaine Maury, Father of Oceanography: A Biography, 1806-1873* (Jefferson, NC: McFarland & Company, Inc., Publishers, [2015]), 160-163, and Chester G. Hearn, *Circuits in the Sea: The Men, the Ships, and the Atlantic Cable* (Westport, CT: Praeger, 2004), 37-40.

for the cruise. The ship left New York at the end of October 1849, well equipped for its mission.[56] Maury's instructions made clear that the ship shared the dual goals inherent in his entire project: its mission was to make observations and collect facts "of practical importance to the safe navigation of the seas, or to the study of the phenomena of the ocean." Walsh was to examine thoroughly the locations of a long list of vigias—a task of clear benefit to safe navigation. Yet this fell sixth on a numerical list, preceded by the more clearly scientific expectations to record hourly meteorological ("thermal, dynamical, barometrical, & the like"), surface and under current, and sea surface temperature readings; soundings and temperature at depth; and salinity, transparency, and specific gravity of the sea water. Bottom specimens "from the greatest depths" were to be brought up whenever possible, and properly labeled and stored for future analysis.[57] Maury's instructions explain the usefulness of many of these readings in explicitly scientific, rather than navigational, terms. Meteorological information, for instance, would help build a better picture of the "general system of the atmospherical Circulation" of the planet," and would allow the "deriv[ation of] an expression to shew the total amount or value of those physical forces which are exerted to put & keep the trade winds in motion."[58]

Walsh was to take *Taney* across the Atlantic to the Canaries, where he would stop only long enough to load water, then south to Porto Praya, in the Cape Verde Islands, and south again to look for a few more vigias and to examine "a supposed submarine volcanic region of considerable extent." From there, he was to return west across the Atlantic to

[56] *Lieut. Maury's Investigations*, 30.

[57] Maury, "Program of Instructions for the 'Taney', drawn by request, for the Secretary of the Navy," 4 October 1849; Volume 4, February 1849 to January 1850 (Vol. 4); LS; RG 78; NAB.

[58] Ibid.

Cabo Saõ Roque, then "proceed to make a zigzag course along the coast to the Northward for the purpose of investigating the currents." After thoroughly charting the currents at the mouth of the Amazon,

> you will proceed Homeward by the following route: From N- Equator in Long 37° W draw a straight line to Cape Charles. This line will lay nearly in the middle of a strip of ocean about 300 miles broad, and which is remarkable for the temperature of its water. You will sail a zig zag course through this strip, crossing it at least 4 times on your way Home, and passing the line, which you are directed to draw, at least 200 miles on either side, and taking deep sea soundings before you put about to re-cross it again. Should you discover anything remarkable as to the depth of the sea within this region you will push the discovery to a conclusion.[59]

This planned course is noteworthy for a number of reasons, most immediately in that it was clearly not chosen to test Maury's routes. Nor does it confine itself to advancing the cause of navigational safety. Instead, Maury laid out a program of investigation of the Atlantic basin in three dimensions, including measurements and techniques (simultaneous observation of multiple kinds of data at recorded locations, careful bottling and labeling of samples, a zig-zag course across the area of interest) that are recognizably oceanographic in nature, and which rely entirely upon the technological innovations of charts, abstract logs, instruments, and gear for accessing the deep.

Unfortunately for this ambitious program, as Maury later reported, *Taney* proved "utterly unseaworthy."[60] The first leg went well enough; Walsh complained only that the ship was too small, and thus had too few watchstanders to perform all the desired observations. But somewhere between the Canaries and Cape Verde a series of problems began to appear: a leaky seam near the keel, damage to all three masts, and dry rot in the main longitudinal beam holding the ship together. A board of officers gathered from

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[59] Ibid.
[60] *Lieut. Maury's Investigations*, 30.

American ships in Porto Praya determined *Taney* should never have been allowed to leave the shipyard; Walsh was ordered to cancel his mission and limp home immediately.[61] That the ship returned to New York at all speaks volumes for Walsh's skill as an officer and seaman; that he took as many observations as he could safely manage on the way speaks as loudly for his dedication.

In July 1851, Maury got another opportunity and issued similar orders to Lt. Samuel Philips Lee, who would command USS *Dolphin*. Lee left New York in this much-larger vessel in October 1851 and returned in July 1852. Despite suffering leaks of its own—*Dolphin* had received insufficient repair since its previous service in the Western Pacific—this cruise was largely successful in following Maury's plan. Lee's report of the cruise, with track charts and tabulated data, was published in 1854 as a Senate report, and he left a memorandum on methodology, "Points of Practice on Board the Dolphin," for his successor and other future expeditions.[62] This expedition was a significant improvement over the last, not just because of the seaworthiness of the vessel; historian Edward Leon Towle examined both expeditions' logs, methodology, data, and sample reports and concluded that "all point to a notable improvement in both the methodology of deep sea research and the quality and quantity of samples and data."[63]

Lt. Otway Berryman, another of Maury's staff lieutenants, took command of the *Dolphin* under similar orders and headed out at the end of September 1852, though with a different planned route. After surviving a near-fatal storm, Berryman made it across the

[61] J. C. Walsh, Porto Praya, to W. B. Preston, secretary of the navy, 16 Feb 1850, (copy); Entry 7: Letters Received, 1838-1884 (LR); RG 78; NAB.

[62] S[amuel] P[hillips] Lee and H. C. Elliott, *Report and Charts of the Cruise of the U.S. Brig Dolphin, Made under Direction of the Navy Department* (Washington, [DC], 1854), 2.

[63] Towle, "Science, Commerce, and the Navy," 281.

Atlantic to Portugal for repairs before resuming his observational route. Recrossing the Atlantic farther north than his predecessor, Berryman returned to the US at Norfolk, Virginia, and, receiving permission to continue the cruise after further repairs, went on to Ireland, then Cape Verde, and zig-zagged back to the West Indies.[64] Maury would see nothing more from Congress's promise of three ships, but what information he had from the *Taney* and *Dolphin* expeditions had proven the deep sea could be accessed for scientific study if only the right technology could be developed.[65]

Maury sent ocean bottom samples collected by Walsh, Lee, and Berryman in *Taney* and *Dolphin* to microscopist Jacob Whitman Bailey at West Point. [66] These samples contributed to Bailey's own future publications, and Maury lauded the microscopic analysis of bottom samples as providing evidence of the grand scale on which atmospherical phenomenon operated.[67] James G. Dana, at Yale, consulted him on ocean temperature in the Atlantic for Dana's own studies on coral formation.[68] The water samples laboriously collected at various depths and labeled by the *Taney* and *Dolphin*—some 500 of them—were sent to Benjamin Silliman at Yale for analysis (though Silliman apparently decided this was not worth his time).[69]

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[64] Maury, *Explanations and Sailing Directions to Accompany the Wind and Current Charts*, 6th ed. (Philadelphia, 1854), 218-219; and Towle, "Science, Commerce and the Navy," 281-284.

[65] Though Secretary of the Navy James C. Dobbin would in his 1856 annual report cite the voyage of USS *Arctic*, also under Otway Berryman, in the context of the 1849 Act. "Annual Report, 1856," J. C. Dobbin, secretary of the navy, quoted in Jaquelin Ambler Caskie, *Life and Letters of Matthew Fontaine Maury* (Richmond: Richmond Press, 1928), 114-5.

[66] Lee and Elliott, *Dolphin Report*, NOTES [342].

[67] Robert K. Edgar, "An Annotated Bibliography of the American Microscopist and Diatomist Jacob Whitman Bailey (1811-1857)," *Occasional Papers of the Farlow Herbarium of Cryptogamic Botany,* no. 11 (February 1977): 1-26. Maury, *Physical Geography*, 117.

[68] Towle, "Science, Commerce and the Navy," 251 n. 40.

[69] Lee and Elliott, *Dolphin Report*, NOTES [342]; Towle, "Science, Commerce and the Navy," 107-8.

DEVELOPING NEW TECHNOLOGIES FOR NEW SCIENCE

As useful for scientific purposes as Maury found the normal suite of navigational instruments, much of what he wished to know about the oceans remained inaccessible to the compass and sextant. While he continually urged captains to expand their usage of other instruments aboard—the thermometer in particular—he also worked with his lieutenants in advance of the *Taney* and *Dolphin* voyages to develop technologies to investigate specific scientific problems. First, he told Walsh on the *Taney* to optimize his use of instruments available from naval stores—unlike most naval captains, whose instruments were strictly rationed, Walsh was invited to requisition as many as he wanted—and Maury promised a triple quantity of chronometers and sextants. Walsh should also take several patent sounding leads, but since Maury doubted they would work at the greatest depth, a more appropriate one would have to be invented. Sailors had been sounding for purposes of navigation, safety, and chart-making for thousands of years, and the technology was quite simple: Attach a weight—the lead—to the end of line and throw it overboard. When it hit bottom, the length of line expended would measure the depth. The addition of a substance, such as tallow, in which bottom sediment could become embedded would allow the retrieval of bottom samples, which could provide navigational hints as well as scientific information. This worked well in shallower waters, but increasing depth brought complications. The greatest problem lay in knowing when or if the lead had reached the bottom, once the depths were great enough that the shock of contact and slacking of the line could not be felt. At very great depths, the line itself began to weigh more than the lead with which it was charged. This uncertainty led to the recording of a number of depths on the *Taney* and first *Dolphin* cruises which, in light of further experience, Maury judged to be far in excess of the actual depths.[70]

From the start, Maury and his lieutenants developed innovative technological solutions to address the problem of deep-sea sounding. Before *Taney* left port, Maury suggested Lieutenant Walsh try one such device that might provide a more accurate record of distance travelled during descent: a propeller-like screw set in a hollow cylinder, which would rotate through a given arc as it descended a set distance, registering its turns on a dial. Maury was clearly still thinking through the problem as he wrote, developing by the end of the letter solutions to problems that occurred as he described the design.[71] Walsh reported after the voyage having taken soundings with a ten pound weight, Stellwagen cone (for retrieving bottom samples), and "a small instrument (weighing about 6 lbs.) invented by yourself, for indicating the depth reached."[72] Maury also suggested a make-shift design for taking accurate deep water temperatures in the absence of self-registering thermometers, though Walsh was later able to obtain four Six's thermometers, which recorded minimum and maximum temperatures, inserted in metallic tubes with valves, "all fitted for deep sea sounding."[73] Maury suggested enclosing thermometers in a self-closing wooden cylinder for insulation. He advised painting these cylinders white, so that they could be observed as they descended through the water column as a means of observing water transparency.[74]

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[70] Maury, *Sailing Directions*, 6th ed., 214
[71] Maury to J. C. Walsh, Schooner *Taney*, New York, 3 October 1849; Vol. 4; LS; RG 78; NAB.
[72] *Lieut. Maury's Investigations*, 56 n.
[73] J. C. Walsh, Navy Yard, NY, to Maury, 3 October 1849; Box 5; LR; RG 78; NAB.
[74] Maury to J. C. Walsh, 3 October 1849; Vol. 4; LS; RG 78; NAB.

Similarly, Maury addressed the problem of wire twisting during deep hauls, which would result in the loss of a lead, by suggesting the inclusion of a swivel above the lead. *Taney* carried 14,300 fathoms (about sixteen and one quarter miles) of wire "of the best English steel" in five sizes, with the smallest diameters stowed away and the larger wound in increasing size on an iron cylinder. The cylinder was fitted to a removable reel and frame; when in place amidships, the wire led aft from the reel, through a pulley in a fairleader (which kept the wire from being caught under the ship if it drifted), and between fenders into the water. 75 More than a third of the wire was lost when it parted at the reel during a single deep sounding, which later turned out to have been dubious.[76] Walsh kept up his soundings, but they were just the beginning of a series of trial-and-error innovations by Maury and his participants to optimize the fundamental technology of sounding: the line with which the weight and sampling equipment was lowered to the ocean bottom.

When Commodore Warrington ordered naval vessels to record deep-sea soundings daily, they were provided with wrapping twine strong enough to bear a thirty-two-pound shot, in 5,000 and 10,000 fathom lengths, but twine that could bear the weight in short lengths proved unequal to the immense depths involved in actual sounding. The specifications called for the twine to be smooth, either waxed or oiled to minimize friction, and marked every 100 fathoms by means of color-coded silk thread instead of knots.[77] As Lieutenant Taylor of the *Albany* reported, these specifications proved insufficient. After

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[75] A fathom is a measurement of depth equal to six feet. J. C. Walsh, Bordentown, NJ, to Maury, 15 August 1850, in *Lieut. Maury's Investigations*, 56.

[76] Towle, "Science, Commerce and the Navy," 258.

[77] "Directions for Taking Deep Sea Soundings, Prepared by the Bureau of Ordnance and Hydrography, under Authority from the Secretary of the Navy, Dated May 31st, 1850, and Issued to the American Navy," in *Lieut. Maury's Investigations*, 100; *Lieut. Maury's Investigations*, 31.

losing six shot while trying to sound in a heavy swell which strained the line every time the ship was lifted by the waves, they tried lighter weights, but still the line snapped or it played out so slowly they could not be sure of having reached bottom. Two days later they lost eleven shot, in part because knots tied to join the long lengths of twine slipped, but the twine itself was also inferior to the task. He returned specimens of it to Maury to prove how inconsistently it was made. Taylor experimented too with oiled, unoiled, and waxed line, but eventually reported in frustration that "we have lost 25 shot in these few experiments, enough to show that the line is not trustworthy." He suggested good twine of fine flax, either spun to length or carefully knotted.[78] Captain Barron of the *John Adams*, reporting his own soundings attempts, noted having incorporated "the hints given us by the experience of Lieut. Taylor" in his practice.[79]

Lt. John M. Brooke, ordered to the depot in late 1851, soon became interested in a particular facet of the deep-sea sounding problem. Once a successful sounding cast was made, the twine was not capable of hauling up the heavy shot with which it was weighted. These were fairly disposable items, so the loss when the line was cut was not great, but it prevented retrieval of a sample (which also meant no positive proof the bottom had been reached). Brooke's idea, proposed and then demonstrated to Maury in early 1852, was to weight the line with a detachable shot, released upon impact with the bottom. A hole bored or cast through it held a lightweight cylinder which would remain attached to the line

[78] "Account by Lieutenant Wm. Rodgers Taylor of Deep-Sea Soundings Taken on Board the U. S. Ship Albany, Commander Platt, by Order of Commodore Lewis Warrington, Chief of the Bureau of Ordnance and Hydrography, 1850," in *Lieut. Maury's Investigations*, 31-34.

[79] Maury, *Explanations and Sailing Directions to Accompany the Wind and Current Charts*, 5th ed. (Washington, [DC], 1853), 224.

and be hauled back up with a bottom sample.[80] As Maury explained to chief of the Bureau of Ordnance and Hydrography Duncan N. Ingraham in 1857, the Brooke sounding device "proposes to bring up specimens of the bottom—not to tell the depths. . . . The depth is told by the time and rate according to which the shot sinks." This was a means of more accurate depth measurement which Maury and his lieutenants had devised based on Walsh's and Lee's records of the time each of their sounding casts took to play out to specific depths. When the line slowed, the bottom had likely been reached. To Maury, the Brooke device's "excellency" was in its simplicity, economy, and accessibility; "excepting the twine, every man-of-war, of whatever nation, is already provided with everything requisite for assisting us in carrying out this plan of deep sea soundings."[81]

Some of these technologies proved more useful than others; during the Taney cruise, Walsh would lose Maury's propeller device during a deep sounding, and the Six's thermometers, along with the wooden cylinders that contained them, succumbed to pressure at depth.[82] The innovative timing technique and the Brooke sounding device were of more lasting value. Instructions for the device's use were soon promulgated to the fleet, Brooke used his device on the North Pacific Exploring Expedition, and it was used and later adapted by British expeditions.[83] Observers were now able to gather specimens such as the ones Berryman collected on *Dolphin*. As British naturalist C. Wyville

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[80] George M. Brooke, *John M. Brooke: Naval Scientist and Educator* (Charlottesville: University Press of Virginia, 1980), 55-56.

[81] Maury to Ingraham, 16 January 1857; LR; RG 45; NAB.

[82] Maury to Ogden, 15 March 1851; Vol. 6; LS; RG 78; NAB. Towle, "Science, Commerce and the Navy," 252 n 44.

[83] Brooke, *John M. Brooke,* 60-134; C. Wyville Thomson, William Benjamin Carpenter, and John Gwyn Jeffreys, *The Depths of the Sea: An Account of the General Results of the Dredging Cruises of H.M. SS. 'Porcupine' and 'Lightning' . . . ,* 2d ed. (London, 1874), 213-214.

Thomson noted later, "These trophies from any depth over 1,000 fathoms were eagerly sought for by naturalists and submitted to a searching microscopic examination."[84]

These instruments and techniques developed by Maury and his staff for their deep sea expeditions provide evidence of his intentions and his approach to problem-solving. Maury clearly understood the deep ocean as an arena for scientific investigation, and he intended these technologies as a means to observe an otherwise inaccessible area.[85] Of course, getting the information was only half the battle. As anyone who has ever worked with a large data set will understand, working with novel and complex information from a vast, three-dimensional area made the processing of the data thus acquired a large part of the problem to be solved. And for this, too, Maury turned to technology.

CHARTS AS TECHNOLOGY OF SCIENCE

The wind and current charts and their successors, the technology for which Maury is most famous, were in fact intended for two purposes. On one hand—the one with which he sold them to Congress and to the public—they were clearly of benefit to navigators, and through them to sailors kept safe, captains kept on schedule, merchants and insurance companies kept in the black, and the nation kept in the front rank of commerce and exploration. Their usefulness for this purpose was as both repository of knowledge and means of communicating that knowledge. The visual medium was the best way to accomplish this, as Maury explained to John Quincy Adams early in the project, because it communicated the information "at a glance, & with a perspicuity, certainty &

[84] Thomson, Carpenter, and Jeffreys, *Depths of the Sea*, 21.
[85] Maury to Ogden, 15 March 1851; Vol. 6; LS; RG 78; NAB.

generalization that written accounts cannot give. Books, if I may so say, impart information through the ear—these charts through the eye & there fore in a manner & form much more condensed & available."[86]

Maury imagined them as physically shortening the distances involved in sea travel. With the knowledge of wind and current embedded in the charts, "Navigators will bring France and the U. States nearer together, by shortening the time between them several days," and indeed, "the Southern hemisphere and all places . . . will be brought closer to the U. States by some days." This magnified the cost savings achieved, for not only did the charts reduce losses and speed deliveries, but they would, Maury said, prevent the need to spend immensely more on canals. The idea of canals as short cuts across Suez and through Central America had already been contemplated for years, but, Maury pointed out, such projects would cost millions of dollars. His charts, on the other hand, were "an enterprise more humble in its pretensions . . . but scarcely less rich with promise of results."[87] The famous exploits of the clipper ships seem to have proved him correct, at least during a brief window in time.

Yet as important as charts were to the art of navigation, they were equally so for formulating a science of the seas. This was perfectly in keeping with the Humboldtian agenda. Humboldt himself was known for his intricate, full-color, carefully coded maps that displayed the distribution of vegetation, and with which he was able to formulate

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[86] Maury, National Observatory, Washington, DC, to John Q. Adams, Washington, DC, 17 November 1847; Vol. 2; LS; RG 78; NAB. Eugene S. Ferguson, *Engineering and the Mind's Eye* (Cambridge, MA: MIT Press, 1992).

[87] Maury to Robert Walsh, 24 January 1848; Vol. 2; LS; RG 78; NAB.

scientific problems and potential answers.[88] Maury's charts served a similar purpose for the oceans. Upon a canvas so vast, only the visual display of the nearly as vast quantities of data collected through Maury's program would allow scientists to see patterns and follow them across the stretches of ocean, to display the interactions of ocean and atmosphere, and to perceive the dimensions of the deep sea. From this information Maury theorized the interdependence of tropical and European climate through the movement of the Gulf Stream.[89] He had a very technological, mechanical understanding of the world, though this in no way undercut his sense of the wonders in the deep. I indeed, he believed that anyone who studied the oceans would gain an appreciation for their intricacies as wonders. To the studious, the sea "becomes as the main-spring of a watch; its waters, and its currents, and its salts, and its inhabitants, with their adaptations, as balance-wheels, cogs and pinions, and jewels."[90] Like a watch, then, the parts of the ocean-atmosphere system could be traced and their functions understood, and his charts provided the technology through which to visualize its workings.

His track charts soon evolved into more complicated and esoteric visual technologies, which reformulated the information on the first charts or included the representation of more variables. While the pilot charts were clearly of direct navigational utility, others—such as the storm and rain and the whale charts—showed scientific promise as well. Maury hoped the former would allow him to resolve the potential effect of the moon on trade winds and calms.[91] The appeal of the latter to

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[88] Lorraine Daston, "On Scientific Observation," *Isis* 99, 1 (March 2008): 108.
[89] Maury to Robert Walsh, 30 December 1847; Vol. 2; LS; RG 78; NAB.
[90] Maury, *Physical Geography*, 58.
[91] Maury, *Sailing Directions*, 5th ed., 250.

whalers might partly have been in their granting the appearance of a scientific approach to a global commercial enterprise upon which an important sector of the American economy relied and which was already beginning to show signs of strain. But Maury was also able to draw scientific conclusions from the information thus encoded about cetacean habit and habitat and even about geography.[92] The thermal charts are arguably more useful to science than to navigation; Maury himself was sure studying them would "reward the student with new and better ideas as to the system of oceanic circulation."[93]

Following the second *Dolphin* voyage, when Lieutenant Berryman crisscrossed the North Atlantic taking the most accurate soundings to date in the deep sea, Maury developed both bathymetrical charts and cross-sections of the Atlantic, revisualizing the bottom of the sea from a great blank space to a physical topography. These charts were rudimentary and preliminary; even with the growing collection of sounding data, the number of data points available remained tiny—a few dozen—in comparison to the expanse of the Atlantic. Still they had immense practical value, They led, for instance, to the identification of the so-called "Telegraphic Plateau," a stretch of apparently mild topography across the North Atlantic that Maury described to secretary of the navy James C. Dobbin as appearing as if it had been set there for the express purpose of receiving a cable.[94] Maury thus showed the potential utility of deep-sea soundings. Anticipating

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[92] D. Graham Burnett, "Matthew Fontaine Maury's 'Sea of Fire': Hydrography, Biogeography, and Providence in the Tropics," in Felix Driver and Luciana Martins, eds., *Tropical Visions in an Age of Empire*, 113-136 (Chicago: University of Chicago Press, 2005).

[93] Maury, *Sailing Directions*, 5th ed., 272.

[94] Maury to Hon. J. C. Dobbin, secretary of the navy, 8 November 1856, quoted in Caskie, *Life and Letters of MFM*, 111-2. Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea* (Cambridge, MA: Belknap Press of Harvard University Press, 2005), 237 (note 37 to page 82).

many an advocate for "pure" science, Maury argued that knowledge of the physical facts must precede any useful purpose for their employment.

While sometimes useful, and frequently novel, these visual technologies were neither more nor less suited to their tasks than were the sounding instruments. Yet the conception of Maury's charts required a systematic view of the oceans as knowable and representable, and of the variables in question as valid ways of measuring and imagining the territory they encompass. The charts were thus visualizing technologies which displayed many thousands of observations in a format which allowed the scientist to perceive the vast horizontal and vertical distances in three dimensions. Thus rendered visible, patterns and relationships—as well as lacunae and anomalies in the data—could be more easily perceived, enabling the formulation of hypothesis and theory as well as of plans for future work.

CONCLUSION

Despite Maury's best efforts to gather data and to represent them in a useful format, he was ultimately unsuccessful in his attempt to formulate the laws which govern the action of ocean and atmosphere. As naturalist C. Wyville Thomson, who would accompany the British *Challenger* expedition in the 1870s, described Maury's cross-section of the Atlantic twenty years later, "Nothing . . . can give a more erroneous or exaggerated conception of its outline than the ideal section in Captain Maury's 'Physical Geography of the Sea,' *although it is in a certain sense correct*."[95] It also, as Thomson's observation on the desirability of "trophies" from the depths suggests, proved foundational

[95] Thomson, Carpenter, and Jeffreys, *Depths of the Sea*, 235 (emphasis added).

to the work of many others since. D. Graham Burnett has posited that Maury's unlocking of the depths—colored by his religious faith in a god responsible not only for creating the wonders in the deep, but for making them part of a clockwork universe that obeys physical laws—transformed the oceans from chaotic and impenetrable to ordered and inherently knowable. This transformation, alongside the many other changes in attitude to ocean and to science in the mid-nineteenth century, made the oceans a place worth investigating scientifically.[96]

That Maury was head of the Naval Observatory as well as the Depot of Charts and Instruments provided him a useful model.[97] He referred to his lieutenants and midshipmen as observers when they stood behind their telescopes, and to his corresponding mariners as observers at sea. Both investigated the inaccessible, granted access only by their increasingly sophisticated instruments. The depot's mission of calibration and control was also important, as Maury aimed at the establishment of a standardization of practice in ocean science, a program in which "[t]he instruments used by every co-operating vessel are to be compared with standards that are common to all; so that an observation that is made any where and in any ship may be referred to and compared with all similar observations by all other ships in all parts of the world."[98]

In this context, Maury's investment of time and energy in technology as the answer to the puzzle of the ocean depths established a pattern of investigation reliant on

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[96] Burnett, "Matthew Fontaine Maury's 'Sea of Fire': Hydrography, Biogeography, and Providence in the Tropics," in *Tropical Visions in an Age of Empire*, ed. Felix Driver and Luciana Martins, 113-136 (Chicago: University of Chicago Press, 2005). Rozwadowski, *Fathoming the Ocean.*

[97] Maury was not alone in taking the observatory as a model for undertaking other scientific investigation. See, for instance, Eric L. Mills, "Exploring a space for science: the marine laboratory as observatory," *Estudios de historia das ciencias e das téchnicas* 1 (2001): 51-58.

[98] Maury, *Physical Geography*, xi. Antony Adler, "The Ship as Laboratory: Making Space for Field Science at Sea," *Journal of the History of Biology 47*, no. 3 (August 2014): 333-362.

technology as the only way of moving forward. This pattern included an emphasis on the importance of government support for science and the promotion of practical results as an accessible outcome of such support. Though perhaps unpopular with his professional contemporaries in the US, Maury's untiring public outreach and engagement was essential both to securing and maintaining government support and to establishing a culture of iterative experimentation with instrumentation and technology and of sharing, to include sharing of instrumentation, best practices, and data and its visual representation.

Maury was by no means the only individual investigating the oceans in the mid-nineteenth century; indeed, his program relied upon a joint effort of many observers and inventors on land and at sea, in America and elsewhere. Nor was his appeal to the government unique; William Whewell certainly had the support and cooperation of the Admiralty in his efforts to understand the tides in the 1830s, and both efforts had a contemporaneous analogue in the British magnetic crusade, with whose committee Maury corresponded.[99] And finally, his insight that technology would be the crucial piece of the ocean science puzzle was not, perhaps, a fresh one, for the British tidal scientists had already discovered the utility of self-registering tidal gauges, and the importance of visual technologies for representation and the formulation of theories.

What was unusual about Maury was the scope of his ambition. While understanding the earth's tides or its magnetism is hardly a small program, Maury envisioned an all-encompassing study of the oceans and atmosphere, from every angle and at every depth, to discover every physical law. The very scope of the program condemned

[99] Michael S. Reidy, *Tides of History: Ocean Science and Her Majesty's Navy* (Chicago: University of Chicago Press, 2008).

it to incompletion in his lifetime, even had he not abandoned it when he joined the Confederacy in 1861, his career a minor casualty among the many major ones of the American Civil War. But the broadly conceived, technology-centric investigation of the oceans would long outlive him, providing both concept and starting point for programs that followed.

CHAPTER 2: The Scientific Circumnavigation of HMS Challenger

[I]t may be taken that the Science of Oceanography was born at Sea, in Lat. 25° 45′ N., Long. 20° 14′ W., on 15th February, 1873.

— John Young Buchanan[1]

John Young Buchanan, a graduate of the University of Glasgow whose family's wealth had allowed him to study chemistry across Europe, joined the scientific staff of HMS *Challenger* in 1872 as expedition chemist. It was onboard this vessel that he watched, along with the other members of the scientific staff and the officers and crew of the ship, as a dredge full of ice-cold muck from the bottom of the Atlantic nearly three kilometers below their keel was emptied on the ship's clean-scrubbed deck. Expedition chief naturalist Professor C. Wyville Thomson used the residual coolth of the mass of red clay to chill a celebratory bottle of champagne. They were less than two months out of England, but with this haul the naturalists felt their initial warm-up period was over and the real work of exploring the ocean floor had begun. They had three years of expedition and tens of thousands of sea miles yet ahead of them. The ship had been specially modified and equipped for its task, and as their experience grew, they would continue to adapt the technologies with which they accessed the deepest oceans, largely replacing the dredge with a much-modified trawl and developing equipment and techniques to process samples and to calibrate and correct thermometers in the shipboard environment. In the process, they were creating a new kind of ship, and perhaps a new kind of scientist.

The *Challenger* Expedition was a joint project of the Royal Society of London and the British Admiralty, and Buchanan is not alone in pointing to it as the origin of

[1]Buchanan, *Accounts Rendered of Work Done and Things Seen* (Cambridge: Cambridge University Press, 1919), xiii.

oceanography as a science (though he is more geographically and temporally specific than most). Historians of science have frequently tied the shift of ocean science from the littoral to the open ocean to the congelation of oceanography as a distinct field. Yet while *Challenger* was certainly revolutionary in the sheer scope of its object—an attempt to study the entire ocean, in three, global dimensions—it was the realization of a pattern of technological tinkering, a pattern which itself constituted the change in scientific practice which made the three-dimensional global ocean suddenly seem accessible to naturalists in a way that their predecessors might have dreamed but could neither attempt nor achieve. This shift brought academic naturalists like Buchanan and Thomson into a working relationship with naval officers, broadening the potential scope of their study through the adoption and adaptation of naval technologies and the deep pockets of government support. Simultaneously, however, this shift transformed ocean science into an occupation reserved for a few, well-connected, male scientists, whose social and scientific standing admitted them to the restricted deck of a warship. Oceanography would remain more exclusive than inclusive for decades to come.

ORIGINS OF THE EXPEDITION

The immense effort of the *Challenger* Expedition did not arise in isolation. It—and the partnership between ocean-going science and government it required—was built over several years upon a foundation of precedent. The Royal Society had negotiated passage for naturalists on ships many times before, although most of these were coincidental; the naturalists' object was a distant and unfamiliar land, and a ship was the only way to get there. Joseph Banks's famous inclusion on James Cook's first voyage to Tahiti in the latter part of the eighteenth century followed this model. Some few voyages were perhaps more ocean-centric, such as Edmund Halley's voyages in the *Paramore* at the turn of the eighteenth century. Halley's interests were in the tides and in charting the earth's magnetic field—both topics of great usefulness to the British government's desire to rule the waves.[2] Yet the three-dimensional ocean was still not his focus.

These early expeditions established some patterns that would prove important to ocean science, however. For one, they created a path to membership in the community of recognized scientists, in the body of the Royal Society, through travel and exploration, a path that would later be taken by naturalists like Charles Darwin as well as more ocean-centric scholars. They also established mutually-beneficial links between the Society and the Admiralty, which would bear their greatest fruit when officers from the Admiralty were also active fellows of the Royal Society, such as Secretary of the Admiralty J. W. Croker, and his subordinate John Barrow in the early nineteenth century.[3] Over the course of the nineteenth century, every Hydrographer of the Navy save one was a fellow.[4]

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[2] Halley's experience was unique, as he was even appointed master and commander, despite his lack of seagoing experience, in order to provide him with authority over the crew. This failed, to the degree that having a "philosopher-commander" was never tried again, though Halley was able to publish a map of magnetic variation in the Atlantic in 1701. Michael Reidy, *Tides of History: Ocean Science and Her Majesty's Navy* (Chicago: University of Chicago Press, 2008), 35-36.

[3] Barrow (1764-1848) became a fellow of the Royal Society in 1806, shortly after assuming his Admiralty post, and retired from the Admiralty only in 1845. Marie Boas Hall, *All Scientists Now: The Royal Society in the Nineteenth Century* (Cambridge: Cambridge University Press, 1984), 3; 199; 252. Croker became a fellow in 1810, shortly after assuming his own post, and stayed at the admiralty for twenty-two years. Hall, *All Scientists Now,* 3; Archibald Day, *The Admiralty Hydrographic Service, 1795-1919* (London: Her Majesty's Stationery Office, 1967), 13 n 2.

[4] Day, *Admiralty Hydrographic Service*, 10.

Studies of use to the imperial project, then, were easy to justify supporting. The scientific exploration of the sea itself was less directly relevant to the navy's work, though individual officers with scientific interests offered occasional opportunities, such as the captain who in 1841 invited anatomist Edward Forbes to gather marine organisms from the deck of HMS *Beacon*.[5]

Forbes's efforts are important to the *Challenger* pre-history as more than just a precedent for conducting ocean science on naval vessels. Beginning in 1839, he had become interested in using the dredge to procure specimens of bottom-dwelling life for scientific study. Forbes was hardly the first naturalist to do so; European naturalists had adapted the oyster dredge for this purpose as early as the late seventeenth century.[6] Forbes picked up both the practice of dredging and an interest in marine invertebrates while a student at the University of Edinburgh, which had become a center of scientific dredging practice.[7] C. Wyville Thomson, who had also been educated at Edinburgh, shared this enthusiasm for dredging, and became an active member of the British Association for the Advancement of Science (BAAS) dredging committee, which Forbes had founded.[8] In the mid-1860s he paid a visit to Sweden, to examine the work of

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[5] Forbes was not yet a fellow of the Royal Society, so this trip was not a result of their influence. Hall, *All Scientists Now*, 211; Margaret Deacon, *Scientists and the Sea, 1650-1900: A Study of Marine Science*, 2d ed. (Brookfield, VT: Ashgate, 1997), 281; Antony Adler, "The Ocean Laboratory: Exploration, Fieldwork, and Science at Sea," Ph.D. Dissertation (University of Washington, 2014), 15. William A. Herdman, an oceanographer turned early historian of oceanographer, included Forbes as his first subject in his *Founders of Oceanography and Their Work: An Introduction to the Science of the Sea*, (London: Edward Arnold & Co., 1923).

[6] Helen M. Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea* (Cambridge, MA: Belknap Press, 2005), 100.

[7] Rodolfo John Alaniz, "Dredging Evolutionary Theory: The Emergence of the Deep Sea as a Transatlantic Site for Evolution, 1853-1876," Ph.D. Dissertation (University of California, San Diego, 2014), 42.

[8]Alaniz analyzes dredging at Edinburgh as a scientific practice in some depth in his "Dredging Evolutionary Theory."

zoologist and theologian Michael Sars. Sars has identified some unusual bottom specimens dredged from 300 fathoms by his son Georg Ossian Sars.[9] This depth was considered extreme both because of the technical challenge to any naturalist without access to a large vessel—the younger Sars had this in his role as a fisheries inspector for the Swedish government—and because Forbes had, years earlier, postulated that life would not be found below that level, a theory which became known as the azoic theory. Thomson saw in these specimens a chance to disprove the azoic theory, which had become dogma in academic circles despite the preliminary nature of Forbes's hypothesis in part because of his tragically early death.[10] But if life indeed existed at great depths, Thomson realized it might also consist of the intermediate species Darwin had predicted would be found in the seas, thus providing an opportunity to prove, or disprove, the latter's recent assertions about the origins of species.[11]

Back in Ireland, Thomson shared one of the Sars' crinoid specimens with William B. Carpenter, a zoologist and physiologist seventeen years his senior, who had participated in several summer dredging expeditions.[12] Thomson proposed they organize a deep-sea expedition of their own, and at Carpenter's prompting put the proposal in writing to serve

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[9] A fathom is measure of depth equaling six feet. Thomson to William B. Carpenter, 30 May 1868, reproduced in Carpenter, "Preliminary Report of Dredging Operations in the Seas to the North of the British Islands, Carried on in Her Majesty's Steam-Vessel 'Lightning,' by Dr. Carpenter and Dr. Wyville Thomson, Professor of Natural History at Queen's College, Belfast," *Proc R Soc* 1868 17: 198 (hereafter cited as "Lightning Preliminary Report.")

[10] Other evidence for life at great depth had been slowly accumulating, including dredged specimens, though some naturalists questioned the provenance of the creatures thus gathered (i.e., was the depth sounded accurately? Did the dredge catch them on its way back up?) The most convincing proof came in the form of living specimens encrusted on a telegraph cable retrieved from a depth of between 2000 and 2800 meters (1093 to 1577 fathoms) for repair in 1861. Carpenter, "Lightning Preliminary Report," 182.

[11] As Alaniz has shown, Forbes had "used crinoid fossils to explore the morphological relationships between ancient extinct and extant organisms," so the leap to using the living crinoids the Sars had found would have been obvious to Thomson. Alaniz, "Dredging Evolutionary Theory," 228-229.

[12] Alaniz, "Dredging Evolutionary Theory," 231; Rozwadowski, *Fathoming the Ocean*, 147.

as the basis for a proposal to the Royal Society to ask for the Admiralty's help. After all, Thomson noted, "Such an undertaking would . . . owing to the distance, and the labour involved, be quite beyond the reach of private enterprise."[13]

As Thomson hints, deep dredging required a vessel of some size for several reasons. One, of course, was its ability to stay on station, which called for steam technology. While small steam vessels existed and naturalist dredgers had in fact been hiring rented steamers already, they lacked the coal capacity to travel to truly deep water and then stay there. The sheer weight of the gear also mandated a larger vessel; even for a dredge of the same size, increasing depth increased the length, and so weight, of hempen rope required to lower and raise it. Thus a deep dredge required a steady platform from which to raise this rope, enough deck space to lay it out, and a large enough crew to provide the muscle—or an auxiliary steam engine to do the heavy lifting. All of these things would be available in a naval vessel, and conveniently, Carpenter noted in his letter endorsing Thomson's request, there were "an unusual number of gun-boats and other cruisers on our northern and western coasts, which will probably remain on their stations until the end of the season." Beyond the desirability of steam, and if possible of a "donkey" or auxiliary engine, they did not even require a very modern vessel. Indeed, "one capable of making way under canvas, as well as by steam-power" would reduce the requirement for frequent coaling, and "as our operations must necessarily be slow, *speed* would not be required." (Though they may have come to regret this caveat.) Carpenter

[13]Thomson to Carpenter, 30 May 1868.

also pointedly noted that the Sars' work had been done under Swedish government sponsorship. [14]

Since both the Royal Society and the University of London, where Carpenter served as registrar, were based at Burlington House, in London, and he was himself a vice president of the Royal Society, Carpenter likely ran the proposal past at least Royal Society President Edward Sabine, a British artillery officer who had played a central role in the government-sponsored geomagnetic studies often called the "Magnetic Crusade," before formally forwarding Thomson's request on 18 June 1868.[15] The Council of the Royal Society endorsed the request the same day, forwarding it to the Admiralty with a note that they would contribute £100 from the Society's Donation Fund to cover scientific supplies.[16] The two naturalists had suggested a summer cruise, to fit both their school schedules and the navy Hydrographic Office's usual surveying season, so there was little time to waste. By mid-July the Admiralty had approved the plan, and HMS *Lightning* was being made ready at Pembroke for immediate operations.[17]

The 1868 summer dredging cruise on HMS *Lightning* serves as a classic reminder to be careful what you ask for. On paper, it matched their every request: a steam-powered vessel with an auxiliary "donkey" engine for retrieving dredges. But the Admiralty apparently took seriously their lack of need for speed. *Lightning* was a wooden

[14] Emphasis in the original. Carpenter to Edward Sabine, President of the Royal Society, 18 June 1868, reproduced in Carpenter, "Lightning Preliminary Report," 197-8.

[15] Hall, *All Scientists Now*, 190-191.

[16] Carpenter to Sabine, 18 June 1868; "Minutes of the Council of the Royal Society, June 18, 1868," reproduced in Carpenter, "Lightning Preliminary Report," 200. The Donation Fund had been established in 1828 as a bequest of Fellow and former President of the Royal Society William Hyde Wollaston, for use "in promoting experimental researches, or in rewarding those by whom such researches may have been made." Hall, *All Scientists Now*, 39.

[17] W. G. Romaine to Sabine, 14 July 1868, reproduced in Carpenter, "Lightning Preliminary Report," 200.

paddlewheel vessel, built in 1823 and, with a sister ship, one of the first steam ships to appear in the Royal Navy list. Its long career included service in the Baltic campaign during the Crimean War in the mid-1850s, but by the late 1860s it was assigned to surveying duties on the west coast.[18] The captain listed the ship's general state of repair as merely "fair"—it had not seen a thorough overhaul since 1864—and projected only three years of useful life left for it.[19] Thomson would later recall the ship as

> a cranky little vessel enough, one which had the somewhat doubtful title to respect of being perhaps the very oldest paddle-steamer in her Majesty's navy. We had not good times in the 'Lightning.' She kept out the water imperfectly, and as we had deplorable weather during nearly the whole of the six weeks we were afloat, we were in considerable discomfort. The vessel, in fact, was scarcely seaworthy, the iron hook and screw-jack fastenings of the rigging were worn with age, and many of them were carried away, and on two occasions the ship ran some risk.

"Still," he added, "the voyage was on the whole pleasant."[20]

Thomson, Carpenter, and the latter's son—along as an assistant—met the ship in Oban, Scotland the first week of August, then shifted to Stornoway to coal.[21] They left Stornoway on the 11th and immediately headed to deep water to dredge, but were interrupted and driven westward by bad weather. When the gale eased, they resumed work briefly, then pulled into Thorshavn, in the Faroe Islands, to coal.[22] The pattern continued over the next few weeks, such that by their return to Stornoway on 9 September,

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[18] A. L. Rice, *British Oceanographic Vessels 1880-1950* (London: Ray Society, 1986), 97.

[19] H. M. Ship *Lightning* Ship's Log, 24 July 1868 to 9 October 1868; ADM 53-9190; The [UK] National Archives (TNA).

[20] Thomson, Carpenter, and John Gwyn Jeffreys, *The Depths of the Sea: An Account of the General Results of the Dredging Cruises of H.M. SS. 'Porcupine 'and 'Lightning ' during the Summers of 1868, 1869, and 1870, Under the Scientific Direction of Dr. Carpenter, F.R.S., J. Gwyn Jeffreys, F.R.S., and Dr. Wyville Thomson, F.R.S.* (Macmillan, 1873), 57.

[21] HMS *Lightning* Ship's Log, 6 August 1868; ibid, 7 August 1868. The sources differentiate them as Dr. (William B.) Carpenter and Mr. (Philip Herbert) Carpenter; though a teenager at the time of the cruise, the latter would become a zoologist in his own right.

[22] D. May [*Lightning*'s captain], to George Henry Richards [Hydrographer of the Navy], 25 August 1868; Box 5: Letters from Surveyors Received in 1868 L-Z; S Papers; UK Hydrographic Office Archives (UKHO).

they had managed only nine days of open-ocean dredging. Only four of these had afforded opportunities to dredge at depths below 500 fathoms. After dropping Thomson off to attend a conference, *Lightning* headed back to sea with the Carpenters to try again, but added only one day's dredging to the total.[23] Dredging at great depths involved a steep learning curve, as well. Initially, for instance, the naturalists weighted the line near the dredge, concerned to keep it at the proper angle; they soon realized the weight of many fathoms of line itself, especially once "solidified" by repeated exposure to the high pressures of the deep sea, performed this function.[24] Innovations added during later cruises would suggest even the few occasions *Lightning* had to dredge wasted opportunities through ill design and inexperience.

Science writer Herbert S. Bailey called the *Lightning* cruise "[i]n many ways . . . an inauspicious beginning. The biological finds were interesting but not spectacular. The depth of sounding and dredging was significant, but deeper dredgings had been accomplished. The main thing was that a start had been made, and it had been shown that a properly equipped ship—one even as poorly equipped as the *Lightning*—could systematically make scientific observations in the depths of the sea."[25] However despite the limited dredging operations, blamed by both naturalists and naval officers on starting so late in the season, Carpenter reported to the Royal Society that the expedition had been "fully as satisfactory as we had ventured to anticipate."[26] They had indeed found life

[23] Carpenter, "Lightning Preliminary Report," 169.
[24] Carpenter, "Lightning Preliminary Report," 171n.
[25] Herbert S. Bailey, Jr., "The Background of the *Challenger* Expedition: The men, ideas, and events that led to the beginning of modern oceanography," *American Scientist 60*, no. 5 (September-October 1972): 553.
[26] Carpenter, "Lightning Preliminary Report," 169.

below the so-called azoic limit; in fact, their deepest dredge—650 fathoms—suggested no depth limit on life existed. Unexpected temperature patterns also suggested new approaches for charting the circulation of the ocean. These results were thus scientifically important in themselves, but as Bailey suggested, they were even more so as a proof of concept. The *Lightning* cruise proved the routine use of the dredge at great depths could not only find novel specimens, but could, combined with sounding and temperature technology, provide important information about the physical environment of the depths.

Key to these successes were the technologies developed for and during the trip, and the personnel who employed them. The *Lightning* cruise proved naturalists and naval officers could cooperate constructively on the open ocean. The naval surveying officers' sounding techniques were used in concert with the naturalists' dredge and temperature to create knowledge stamped with both experts' authority claims. As Thomson put it, the officers "heartily seconded my colleague and myself in our work and sympathised with us in our keen interest in the curious results."[27] Not only did the crew provide expertise in depth finding, station-keeping, and the operation of the dredging tackle and donkey engine, but they collaborated in suggesting technological improvements, as well, drawing from a well of expertise in naval equipment and its operation at sea which the naturalists thus far lacked.

Uncomfortable though the trip may have been, Thomson and Carpenter were eager to follow up on its scientific promise. Carpenter presented their preliminary report at the Royal Society's December 1868 meeting, ending with a call to extend the investigation

[27] Thomson, Carpenter, and Jeffreys, *Depths of the Sea*, 58.

"both in range and objects."[28] And indeed, the following month the Society resolved to pursue another, expanded expedition. A committee was formed to organize it, consisting, in addition to the president and officers of the Society, of Carpenter; the conchologist John Gwyn Jeffreys, who had retired from a law career to pursue scientific dredging; and, significantly, Hydrographer of the Navy Captain George Henry Richards.[29] Historian Robert E. McCabe has noted the importance of Richards' position on the committee that organized the later *Challenger* expedition; Richards the committee member was able to guide the writing of a request that would then be sent to Richards the hydrographer, almost guaranteeing its approval.[30] Yes clearly his interest in and involvement with the deep-sea dredging project began much earlier.

The committee noted that the deep sea was, in fact, "a vast field for research" into not just biology, but also geology and the physical sciences, and one which they hoped the navy might eventually take on as "one of [its] special duties" since "the prosecution of such a systematic exploration is altogether beyond the reach of private enterprise, requiring means and appliances which can only be furnished by Government." For a start, they proposed continuing the work begun on *Lightning* near Scotland and the Faroe Islands, to investigate the conditions surrounding a strong temperature gradient found on the bottom as well as attempt still deeper dredges. Learning from the previous summer's mistakes, they proposed an earlier start and a larger ship; the naturalists would fit it into their busy

[28] Carpenter, "Lightning Preliminary Report," 195-6.

[29] Carpenter, J[ohn] Gwyn Jeffreys, and [Charles] Wyville Thomson, "Preliminary Report of the Scientific Exploration of the Deep Sea in H.M.Surveying-Vessel 'Porcupine,' during the Summer of 1869," *Proc R Soc* 1869 18: 398 (hereafter cited as "1869 Porcupine Preliminary Report.")

[30] McCabe, "Admiral George H. Richards, RN, and the Contributions of the Royal Navy to the Science of the *Challenger* Expedition," Master's Thesis (The Johns Hopkins University, 2006).

academic schedules by dividing the summer into three blocks (they referred to these as separate cruises), with Gwyn Jeffreys, Thomson, and Carpenter serving in turn as "Chief," and seconded by two scientific assistants furnished by the Society in addition to the ship's officers. The Society assigned a committee to consider instruments, and this time promised a grant of £200 from the Government Grant.[31] The early start, and no doubt Richards' shepherding of the request, allowed an affirmative response from the Admiralty by mid-March—delivered verbally by Richards—followed by an offer to entertain the naturalists onboard HMS *Porcupine* at government expense.[32]

Though still a paddle-wheel gunboat, the *Porcupine* was a more suitable ship not only because it was twenty-one years younger. Fifteen feet longer, slightly wider at the beam, and with one third again the horsepower, *Porcupine* was a veteran survey ship which had also seen Baltic duty and assisted in laying the ill-fated 1858 transatlantic telegraph cable; while surveying a better route for the eventual successor cable in the early 1860s, the ship had performed some dredging work off the coast of Ireland. Captain Edward Killiwick Calver had been in command since 1863, no doubt an important factor in the smooth operation of both equipment and crew during the naturalists' summer excursions.[33] The cruise reports from the summer of 1869 contain none of the dramatic complaints of the previous effort.

[31] "Report of the Committee on Marine Researches," reproduced in Carpenter, Jeffreys, and Thomson, "1869 Porcupine Preliminary Report," 398-401. The Government Grant was established in 1849 at the suggestion of Lord John Russell, then First Lord of the Treasury, and consisted of a ₢1000 grant from the Treasury to be used "to promote science." The 1869 grant was thus a significant portion of the annual funding, and meant the *Porcupine* cruise relied entirely upon government patronage, although the allocation of funds was in the Royal Society's hands. Hall, *All Scientists Now*, 163. The request was transmitted by letter; W. Sharpey to the Secretary of the Admiralty, 18 February 1869, reproduced in Carpenter, "1869 Porcupine Preliminary Report," 400-401.

[32] W. G. Romaine to [Sabine,] President of the Royal Society, 19 March 1869; MC-8-337; RS.

[33] Rice, *British Oceanographic Vessels*, 118-9

As Calver's experience suggests, the personnel decisions surrounding the *Porcupine* cruises demonstrate their importance to success, but also the evolution of practice as the naturalists and their patrons learned from experience, a process that would prove crucial to the organization and success of the *Challenger* expedition. One advantage of the larger ship was a larger crew; more men in each watch section meant more men on deck at any given time to work continuously, a need included in the committee's original request, presumably in response to a the *Lightning* experience.[34] They also asked for a ship's surgeon knowledgeable in natural history. Whether the latter request was met is unclear, but it reflects a growing awareness of the naturalists' reliance on their naval hosts not just for getting them where they wanted to be (and indeed, for telling them where they were, and where their samples came from), but also for the operation and iterative improvement of their scientific technologies. British naval officers in this period tended to specialize; those who entered the field of surveying stayed in it for long careers, as Captain Calver's experience demonstrates. This made them an immense storehouse of knowledge beyond the usual facts of navigation and shiphandling.

While the Royal Society had established a "Special Committee, consisting of Gentlemen practically conversant with the construction and working of . . . instruments" to decide upon the expedition's outfitting, *Porcupine* was also equipped with several technological advances developed within the navy or even aboard the ship.[35] The deep-sea sounding device was one known as the Hydra apparatus, for its development onboard HMS *Hydra* during previous surveying missions; Carpenter later described it as

[34] "Report of the Committee on Marine Researches," 398.
[35] "Report of the Committee on Marine Researches," 398.

not-dissimilar to other such devices then in use: weights carrying the device to the bottom on the end of a long line detached upon impact, allowing attached instruments—such as thermometers and water-collecting bottles—along with a rod or tube which had collected a bottom sample upon impact to be drawn back up to the surface. *Hydra*'s innovations were in the mechanism for detaching the sinkers and in the sample tube.[36]

The dredges were modeled on those found to have worked best the previous summer, but Captain Calver's suggestions to increase the weight and change the dredge's design were adopted after the first cruise, and its inner bag was modified to help prevent the washing out of its contents on the way up—another "ingenious device of Captain Calver."[37] During the planning phase, he suggested the ship be rigged to allow sounding and dredging both fore and aft, which was done; he incorporated rubber accumulators in the dredge tackle, which would bear some of the strain of raising the dredges and absorb any sudden shocks, thus helping to prevent the parting of a dredge line and thus loss of a dredge and its haul; and he devised a system for stowing and rapidly deploying three nautical miles of line along the ship's bulwarks, thus leaving the deck free (a matter of safety as much as of convenience) and preventing kinks in the line.[38]

Calver was responsible for another vital innovation, which demonstrates his investment in the scientific work as much as his ingenuity. "[H]aving noticed that animals frequently came up attached to the part of the dredge-rope that had lain on the ground, or to the net of the dredge itself, [Calver] justly reasoned that if the Sea-bottom were *swept* with hempen brushes, they would probably bring up many creatures that might

[36] Carpenter, "1869 Porcupine Preliminary Report," 405.
[37] Carpenter, "1869 Porcupine Preliminary Report," 406; 426.
[38] Carpenter, "1869 Porcupine Preliminary Report," 406, 404, 406.

escape the *scraping* of the dredge." The dredge was modified with an iron rod across and extending two feet longer than the bottom, and attached to these extensions were bundles of unraveled rope—looking a bit like mops, or, as the sailors called both mop and new scientific accoutrement, swabs. The scientists called them "hempen tangles." This modification proved vital to the picture of the ocean bottom that was developing; where the dredge had been coming up nearly empty on hard bottom, leading the naturalists towards assumptions about the barrenness of these areas, new hauls with the tangles came up "laden with the richest spoils of the Ocean-bed." Carpenter reported that "[t]he result of its employment was so extraordinary, that no deep dredging can hereafter be accounted of any value in which it has not been used."[39]

Much has been made of the supposed friction between naturalist and naval officer during the early British expeditions; as Herbert Bailey put it,

> [O]ne can easily imagine that there was not much enthusiasm for the project among the officers at the Admiralty. What naval officer wants his ship rigged with encumbered derricks and his deck encumbered with miles of rope? What naval officer would with equanimity permit buckets of mud, dredged from the bottom, to be dumped out on his clean deck, so that it could be picked over by scientists? And above all, what naval officer wants a group of scientists aboard, civilians unfamiliar with and ill-adapted to navy routine, with the probability that their needs and desires will interfere with the normal operation of the ship?[40]

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[39] Carpenter, "1869 Porcupine Preliminary Report," 436-437, 406.

[40] Bailey, "Background of the *Challenger* Expedition," 550. These sorts of assertions are by no means unique to the British experience, nor was the threat to cleanliness and routine an officer's only imaginable objection. As Joel W. Hedgpeth noted of the US Fisheries Steamer *Albatross*, for navy personnel "assignment to [*Albatross*] was not always considered advantageous to advancement in the service." Hedgpeth, "The United States Fish Commission Steamer Albatross," *American Neptune* 5, no. 1 (January 1945): 9.

But while such a reaction might indeed be easy to imagine, no evidence exists of such reluctance actually existing on these expeditions.[41] As McCabe has shown, Richards' participation in the planning demonstrates that the Admiralty was in fact quite cooperative, even enthusiastic. On the individual level, Calver appears to have been the answer to Bailey's "what naval officer?" The initiative with which he followed the proceedings well enough to recognize problems and recommend ingenious solutions suggests his enthusiasm for the expedition. The naturalists sang Calver's praises for the precision of his navigation, and his being "perfectly ready to attempt any depth" with the dredge. Indeed, thanks to Calver's "complete mastery" of sounding and dredging operations, "[n]ot a single fathom of line [was] lost, and not a single instrument . . . suffered damage, throughout the whole Expedition" (a claim that definitely could not be made about the *Lightning* cruise).[42] Thomson would later name the *Calveria hystrix*, an echinoderm discovered on the cruise, in Calver's honor, the first of many honorary acknowledgments of naval officers by the naturalists dependent on them.[43]

The naturalists were pleased enough with the summer's work to request the *Porcupine* specifically for the summer of 1870, with a proposal to extend the geographical

[41] Which is not to say friction never existed. During the U. S. Exploring Expedition in the early 1840s, Captain Charles Wilkes famously restricted the embarked naturalists efforts to go ashore or to retain specimens. Commander Cadwallader Ringgold, of the US North Pacific Exploring Expedition a decade later, refused to allow either dirt or smelly work on board, which obviously described most of what the naturalists came along to do. But both officers had run-ins even with naval personnel, leading to Ringgold's relief from command and a singular situation upon Wilkes's return when he and his officers brought each other up on court martial charges. But neither were these the norm. It is likely that most of the time Helen Rozwadowski's observation was true that "[r]elationships between scientists and sailors were fully characterized neither by antagonistic conflict nor by utopian cooperation." Rozwadowski, "Small World: Forging a Scientific Maritime Culture for Oceanography," *Isis* 87, no. 3 (September 1996): 410.

[42] Carpenter, "1869 Porcupine Preliminary Report," 407, 423, 406.

[43] Thomson, *Depths of the Sea*, 157. The genus *Calveria* is now known as *Calveriosoma*. A. Kroh, "*Calveria* Thomson, 1872," in Kroh & R. Mooi, World Echinoidea Databasem 2017. Accessed 20 March 2017, through World Register of Marine Species, online at http://www.marinespecies.org/aphia.php?p=taxdetails&id=123398

scope of operations south and thence into the Mediterranean. Again, Richards's presence on the committee, and familiarity with the ship's availability, likely helped.[44] The Admiralty complied as before with the request, and the ship was overhauled and new gear made up in accordance with the previous summer's most serviceable designs. The expedition received further government support in the form of eight Miller-Casalla thermometers, designed collaboratively between the naturalists, the Hydrographic Office, and their usual instrument maker to protect the self-registering thermometers from the effects of pressure, which the naturalists had realized were skewing their results at depth.[45]

In addition to the development of technology and the perfection of techniques for using it, these short expeditions were establishing organizational precedent that would help in planning a longer expedition. Though the naturalists were not explicit about their reasoning for the change, it is notable that the scientific structure of the *Porcupine* cruises differed from that on the *Lightning*, in that each cruise segment had a designated chief. Having each naturalist participate in and take charge of one segment may just have been an effort to maximize the cruise's length within the confines of the academic summer schedule and each man's busy extracurricular activities, but it had not been the case on the *Lightning*, when both Thomson and Carpenter were underway together for most of the (shorter) trip.

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[44] Committee report read before the Royal Society, 28 April 1870, reproduced in Carpenter and Jeffreys, "Report on Deep-Sea Researches Carried on during the Months of July, August, and September 1870, in H.M. Surveying-Ship 'Porcupine'," *Proc R Soc* 1870 19: 147 (hereafter cited as "1870 Porcupine Preliminary Report.")

[45] Carpenter, "1870 Porcupine Preliminary Report," 150. On the design and testing of the thermometers, see W. A. Miller, "Note upon a Self-Registering Thermometer Adapted to Deep-Sea Soundings," *Proc R Soc* 1869 18: 482-486, and John E. Davis, "On Deep-Sea Thermometers," *Proc R Soc* 1869 18: 347-348.

No doubt one reason for the new need for a designated chief is reflected in the changing makeup of the technical crew. In *Lightning*, the naturalists were forced to do all their own work, assisted only by the officers and crew (and of course by young Mr. Carpenter). By the time of the first *Porcupine* expedition, the apparent lack of any limit to life and the temperature anomalies discovered on the first expedition increasingly suggested the importance of investigating the environment more broadly. Accordingly, the committee "decided that the naturalists directing the expedition should be accompanied by assistants trained in chemical and physical work, and the chartroom of the vessel was fitted up as a temporary laboratory, with physical and chemical apparatus and microscopes."[46] To perform analyses in this first ocean-going laboratory, they would clearly need trained technicians rather than just seconded naval officers; the Royal Society provided "two competent Assistants . . . , who should be engaged for the whole Cruise."[47] They carried equipment designed to test the penetration of light with depth, to record the temperature profile throughout the water column, to return uncontaminated samples of bottom water, and to test specific density and to perform gas analysis on that water.[48] The ship was becoming a laboratory, and carrying to sea with it the kinds of laboratory labor practices then being established ashore.[49]

In addition to refining their previous results, the second summer on *Porcupine* allowed the naturalists to investigate the question of water flow at the mouth of

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[46] Thomson, *Depths of the Sea*, 84.

[47] "Report of the Committee on Marine Researches," 399.

[48] Carpenter, "1869 Porcupine Preliminary Report," 401-2.

[49] On ships as laboratories, largely using the example of the *Challenger*, see Adler, "The Ship as Laboratory: Making Space for Field Science at Sea," *Journal of the History of Biology* 47, no. 3, (August 2014), 333-362, as well as his "Ocean Laboratory."

the Mediterranean, part of a larger attempt to address Carpenter's new theory, based on *Lightning*'s and *Porcupine*'s bottom-temperature evidence, of a thermohaline cause underlying circulation in the global ocean. To follow up on these results in the summer of 1871, Carpenter was offered a berth on the much-larger, wooden, screw sloop HMS *Shearwater*, which was headed to the Red Sea for surveying work under Captain George S. Nares, a veteran surveyor and Arctic sailor. They left early to allow Carpenter a month's investigation in the Mediterranean.[50] Nares wrote in October to inform Richards, "Dr. Carpenter has landed after what he must think a very enjoyable cruise at the govt. expense. he got on very well with all."[51] This was far more than a social nicety, for as they sailed, the Royal Society and others were already discussing the possibility of a much more ambitious voyage, and Richards had big plans for Captain Nares.

Before the second summer on *Porcupine*, Carpenter, in conversation with the other naturalists and fellows of the Royal Society, had broached the idea of a longer and more comprehensive exploration of the sea. By the beginning of November 1869, he developed a formal proposal, calling for a scientific circumnavigation of the globe to study both physical and biological sciences.[52] Meanwhile the Admiralty was quietly making its own preparations. Although the Society's application for a circumnavigation would not

[50] The three ships had been progressively larger and newer as the importance of the work became more obvious and the Admiralty's investment more solid. In terms of length, *Lightning* was 126 feet, *Porcupine* 141 feet, and *Shearwater* 160 feet. Comparison in terms of displacement, the more standard and more useful metric of comparison of ship size, is complicated by a change in units during the period: displacement was computed via a standard formula and expressed in "Builders' Old Measurement" (bm) from 1773 to 1873, and expressed in actual tons of water displaced from 1873. For the three ships: *Lightning* was 296 (bm), *Porcupine* was 382 (bm) or 490 tons, and *Shearwater* was significantly larger at 669 (bm) or 913 tons. *Challenger* would be much larger still at 1462 (bm) or 2306 tons. All figures are from Rice, *British Oceanographic Vessels*, 8, 97, 188, 135, 30.

[51] George S. Nares to Richards, 20 October 1871; Box 9: Surveyors Letters 1871; S Papers; UKHO. Capitalization patterns in the original.

[52] Carpenter to Sabine, 3 November 1869; Sa. 301; RA.

receive official approval until April 1872, Richards, who had again been on the planning committee, had by then made extensive preparations. Certainly by the summer of 1871, Richards had identified *Challenger* as the ship and Nares as its captain, making the *Shearwater* trip with Carpenter, most obvious choice to lead the civilian scientific team, a test run of the leadership personalities, as Robert McCabe has pointed out.[53] At least Nares, and perhaps both of the men, recognized this trial for what it was, but the results seem to have been mixed. While Carpenter may have "got on very well with all," the captain was less impressed with the naturalist's stamina, reporting from Malta that "Dr. Carpenter is rather pulled down by the [hot] weather or perhaps by the good living."[54] By the time they reached Egypt, Nares's misgivings about Carpenter's ability to perform at sea had coalesced into specific concerns. Reporting to Richards that he and the naturalist had talked at length about the planned expedition, Nares asked, "Would he not be more useful at home than on board. to receive and work up the results. I can manage the temperature & density and current work just as well as he can. then with young collectors in each branch of nat'l history, we shall give you good results. Dr. C is too old a man for such a long absence."[55]

Nares was also uneasy with Carpenter's assumption that, as chief naturalist, he would have "the ship altogether for his own work."[56] As a naval officer, no doubt much of Nares's concern was for a clear chain of command, in which the captain retained authority over his ship and crew (though perhaps this is also a hint that Carpenter did not, in fact, get

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53 McCabe, "Admiral George H. Richards," 40.

54 Nares, Malta, to Richards, 2 October 1871; Box 9: Surveyors Letters 1871; S Papers; UKHO.

55 Nares to Richards, 20 October 1871; Box 9: Surveyors Letters 1871; S Papers; UKHO. Emphasis and capitalization patterns in the original.

56 Nares to Richards, 20 October 1871; Box 9: Surveyors Letters 1871; S Papers; UKHO.

on as well with all as reported), but Nares expressed it in terms of keeping the naval personnel invested in their mission: "[Y]ou must give the young naval brain something to work upon even if it lengthens the trip, or the daily ton or two of mud in the dredge will be anything but popular." Nares thus requested *Challenger* be assigned a full slate of surveying and astronomical work, work for which naval officers would be qualified, in addition to the biological dredging they would supervise for the naturalists.[57]

MAKING A SHIP FOR SCIENCE

HMS *Challenger* was a wooden, steam-assisted, screw corvette, of 226 feet length overall and 2306 tons displacement, which normally carried eighteen guns and a crew of 290. The steam-assist meant that, although it had a 400-hp steam engine, the attached two-bladed propeller could be detached and retracted through a well up to the main deck, reducing drag when the ship was under the power of its more than 16,000 square feet of sail. Built in 1858, *Challenger* had thus far pursued, as historian Tony Rice put it, "a fairly undistinguished career," though one that took it to North America and even Australia before a return to England.[58]

The process of altering the ship from warship to research vessel had both official and unofficial components, in which spaces were created or physically changed, and spaces left unchanged shifted in use and found new, scientific purposes. Both naturalists and naval personnel were involved in this process, which started at the yards in Sheerness,

[57] Nares to Richards, 20 October 1871; Box 9: Surveyors Letters 1871; S Papers; UKHO.

[58] Horsepower here is nominal; the ship had an indicated horsepower of 1234. For horsepower as well as other measurements, all figures should be considered close, but perhaps approximate, as they vary between sources. Rice, *British Oceanographic Vessels*, 30-31.

on the coast well east of London, but continued as the ship progressed along its global path. And as other historians have argued, changes in the physical spaces and uses of the ship created and echoed changes in the culture afloat, creating a new hybrid that fully conformed neither to the traditional arrangements of a naval vessel nor to the practices of a shore-based laboratory.[59]

As early as October 1871, Nares wrote Richards from Egypt for a copy of the *Challenger*'s plans (and indeed, he wrote another contact asking for a private copy, because "unless looked after [the Hydrographic office] will take a month making an extra copy").[60] He returned the plans later, marked with suggestions. Aside from some concern that known dry rot be addressed in the yard before they left, he was satisfied that the ship would need very little alteration, though adding cabins on deck for scientific work would have to balance the need for space with the requirement to maintain light and ventilation for a ship that planned extensive work in every climate.[61] Once officially assigned command and back in England, Nares made frequent trips to Sheerness and to the Hydrography office to consult with Richards and to supervise the yard work.

The *Challenger* had been chosen because of the advantages it already had in terms of space and size, and the handling characteristics that size provided. As Thomson later put it, the screw corvette had "all the accommodation of a frigate, with the handiness and

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[59] Rozwadowski, "Small World: Forging a Scientific Maritime Culture for Oceanography," *Isis* 87, no. 3 (September 1996). Adler builds up her argument in "Ship as Laboratory."

[60] Nares to Richards, 20 October 1871. Nares to Blakeney, 19 October 1871; Box 9: Surveyors Letters 1871; S Papers; UKHO. Nares also asked Blakeney for copies of the Pacific Sailing Directions and the Proceedings of the Royal Geographical Society, likely also for *Challenger* planning.

[61] Nares to Richards, 16 January 1872; Box 10: Surveyors Letters 1872; S Papers; UKHO.

draught of water of a corvette."[62] The first, and physically easiest, change effected was perhaps most fundamental to the warship's change in identity: Sixteen of the eighteen guns were removed. This provided great advantages in terms of space saved, as well as providing, in the form of the former gun ports, excellent ventilation and light for the scientific work. But it also not-so-subtly eroded the ship's identity as a warship. To the scientists it was a seamless change; to the naval officers and crew, a more fundamental one, although most if not all of the officers came from surveying duty, where frequent gun drill at sea would not have been the norm. Though they themselves are silent on the issue, the confusion inherent in the result became clear when the ship visited the Portuguese prison colony at Fernando Noronha. There the uniformed governor, upon meeting the crew, demanded to know why the ship had not rendered the salute that would have been customary upon entering a foreign harbor. When told the ship did not have the guns to do so, he was, according to *Challenger* Sublieutenant Lord George Granville Campbell, "confused and perturbed in spirit," perhaps even suspicious.[63] Thomson, as a civilian perhaps less aware of either the potential snub or of the suspicion an oxymoronic gunless warship might evoke, reported that the governor "asked a number of questions which surprised us a good deal from a man in his position. He inquired repeatedly what port in England we had sailed from, and to what English port we meant to return. He did not seem to understand our flag nor the captain's uniform, and asked if the ship had a

[62] Thomson, *The Voyage of the "Challenger": The Atlantic; a Preliminary Account of the General Results of the Exploring Voyage of H. M. S. "Challenger" During the Year 1873 and the Early Part of the Year 1876*, vol. 1. (London: Macmillan, 1878), 27.

[63] George Granville Campbell, *Log Letters from "The Challenger"* (London: Macmillan, 1876; new edition 1881), 27.

commission from the British Government. He did not seem to be quite able to grasp the idea of a man-of-war for scientific purposes, and without her guns."[64]

With the guns removed, several changes were made to the arrangements of the ship's decks. One, again marking a fundamental shift from naval practice, was the division of the after cabin on the main deck in two.[65] This space was usually the domain of the captain, a reservation of tremendous private space relative to that afforded to even the other officers, much less the crew, who berthed communally. The practice put physical walls between captain and crew, reinforcing the symbolic isolation of his position and thus supporting his authority over the ship and everyone on it. *Challenger*'s captain retained the starboard after cabin as his own sleeping cabin, but the port cabin gave the director of scientific staff a sleeping cabin of his own, and of equal size. The fore cabin, which stretched the full width of the ship immediately before the two leaders' sleeping cabins, was shared between the two men "as a sitting-room, the port-end, with writing-table and work-table, and book-cases packed with old home favorites, being appropriated to [the chief scientist's] use and that of [his] secretary," who also served as the ship's artist and scientific illustrator.[66] This allocation of equal private space to scientist and captain underlined the fundamentality of the ship's scientific mission and again worked to subtly shift the ship's identity and the working culture on board.[67]

In front of these, more cabins were built symmetrically on either side of the ship. The after, and larger pair, each about twelve feet wide and twenty feet long, served as the

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64 Thomson, *Atlantic,* vol. 2, 114.

65 The main deck is always the highest deck on a ship that reaches from stem to stern. Any others above that deck are partial.

66 Thomson, *Atlantic*, vol. 1, 27.

67 A point made by Rozwadowski, "Small World," 415.

chart room on the starboard side and the naturalists' work room on the port. The chart room was "the head-quarters of the naval scientific staff, . . . with ranges of shelves stocked with charts, and hydrographic, magnetic, and meteorological instruments." Naval officers conducted these measurements, "as well as the whole of the practical operations in dredging, sounding, and taking bottom and serial temperatures." On the other side, the naturalists's work room was "a novel addition to the equipment of a surveying ship," lit by skylight and glazed sash, outfitted with cupboards and drawers full of bottle and test tube racks, instrument cases, a fresh-water tank and sink, and a (locked) cistern of spirit of wine secured in the overhead netting for preserving specimens. Tools from harpoons to botanical vasculums were suspended from the overhead, and a long table down the center of the room provided a convenient place to use microscopes—secured against movement at sea—in the light provided by the former gunport on the port side.[68] The provisions for chemical analysis even included a glass-blowing forge for the creation or modification of the vessels needed to contain or test samples.

Of course, storage was also vital, both for empty bottles and stocks of fluid and for prepared specimens to be held until they could be crated and shipped home at the next port. The removal of the guns opened up the magazines for other use, and their locked hatches made them useful for the alcohol needed to preserve specimens. This "spirit" was stored in racks in tagged and numbered four-gallon, iron cylinders, with screw taps, which could be emptied into the tank in the work room. The ship's gunner's mate retained charge of the locked space, but his duties now included fetching the appropriate cylinder when requested, "so that it [was] never necessary for any member of the

[68] Thomson, *Atlantic*, vol 1, 27-29.

scientific staff to go down into the magazine."[69] This exclusion would have had as much to do with class as vocation; the naturalists, as gentlemen, properly belonged on the upper decks with the officers instead of below, the realm of the crew. Two hundred crates of specimen jars in three sizes—a total of 2300 jars—were procured and packed before departure, while the ship's tinsmith made zinc cylinders for packing larger animals as needed. The main deck also held the dredging tackle and miles of manila line, which could be deployed from a platform built above the upper deck. A deckhouse for the naturalists' use sat towards the stern.

Further forward on the port side, a photographic lab was set up in two smaller cabins, which served as light and dark rooms. The technician responsible for this work was Caleb Newbold, a corporal of Royal Engineers, who would be replaced in turn by Frederick Hodgeson and Jesse Lay over the course of the expedition. Thomson was himself a photog rapher, and he understood the skill necessary to deal with the adverse conditions at sea, including motion, humidity, climatic extremes, and the air's "vitiation by vapors of various kinds."[70]

SCIENTISTS AND SAILORS

Identification of the personnel who would participate in the *Challenger* expedition was a selective process but not a competitive one. While the Admiralty, and indeed the Hydrographer, selected all of the naval officers and the Royal Society all of the scientific staff, the processes were remarkably similar, in that each demonstrated the importance of

[69] Thomson, *Atlantic*, vol 1, 30.
[70] Thomson, *Atlantic*, vol 1, 46.

connections in Victorian Britain. Richards had known Nares since the latter was a midshipman and had played a key role in his inclusion in an Arctic expedition as a lieutenant in the early 1850s. He had extensive experience as an educator, having written a best-selling seamanship manual, and thus likely seemed a good bet for dealing with a crowd of socially important but inexperienced scientists on board. He also had extensive surveying experience, which meant skills in the hydrography and astronomy that would constitute the physical science side of the mission, and in sounding and dredging, which would support the biological side.[71] Richards had even sent his own son out to serve under Nares in Suez.[72]

Nares was in turn able to select many of his own officers, and he expressed opinions of those chosen by Richards. One of his key choices was Lieutenant Thomas Tizard, who had served under him in the Suez first in HMS *Newport* and then *Shearwater*, and he also took *Shearwater*'s Lieutenant Bethell. Not all of his suggestions were honored (nor did he expect them to be), but Richards did consult him about the appointments he made; Nares so approved of the appointment of Pelham Aldrich as senior lieutenant, for instance, that he said he would have no need of a commander. In this the process of manning the *Challenger* was not much different than that for any other ship; Nares's letter on the subject also mentions several potential replacements for *Shearwater*, notably reminding Richards which men's fathers were friends with the admiral.[73]

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[71] R. N. Rudmose Brown and Margaret Deacon, "Nares, Sir George Strong," Oxford Dictionary of National Biography. Oxford University Press. Accessed 18 May 2015. Online at http://www.oxforddnb.com/view/article/35185?docPos'2

[72] Nares to Richards, 8 November 1871; Box 9: Surveyors Letters 1871; S Papers; UKHO; Nares to Richards, 16 January 1872; Box 10 Surveyors Letters 1872; S Papers; UKHO; Nares to Richards, 24 March 1872; Box 10 Surveyors Letters 1872; S Papers; UKHO.

[73] Nares to Richards, 24 March 1872; Box 10 Surveyors Letters 1872; S Papers; UKHO.

The selection of the staff followed a similar process, though one overseen by a committee, of which Richards was still a member. It may in fact have been via him, and from Captain Nares, that the most controversial scientific appointment was made, or rather, unmade. Carpenter has clearly proposed and organized support for the expedition with the intention of leading it; indeed, this had been the unspoken premise of the *Shearwater* trip. Yet as Nares had related to Richards, he had been unimpressed by Carpenter's suitability for the long journey, suggesting a man of his age (Carpenter turned 59 in 1872) might be more useful at home processing results while younger men did the shipboard naturalizing.[74] The committee—including, after a brief fight, Carpenter—agreed. The next obvious choice was of course C. Wyville Thomson, who was at least as highly qualified, based on his own previous investigations as well as his experience in *Lightning* and *Porcupine*. At 42, Thomson had the maturity and experience to be taken seriously as the expedition's head, but the energy to pursue research in the wide variety of sea states and climatic conditions they could be expected to encounter.[75]

The rest of the scientific staff was appointed by the Royal Society, and certainly emphasized young men with professional training who had previous expeditionary experience of some kind (and therefore represented a sort of known quantity, in terms of being both constitutionally and professionally capable of performing at sea).[76] Naturalist Henry Nottidge Moseley was an Oxford graduate, who had participated in the 1871 Government Eclipse Expedition to Ceylon; he would eventually marry the daughter of

[74] Nares to Richards, 20 October 1871; Box 9: Surveyors Letters 1871; S Papers; UKHO.
[75] Ironically, Carpenter would outlive Thomson; neither man lived to see the completion of the entire, 50-volume *Challenger* Report.
[76] Rozwadowski, *Fathoming the Ocean*, 166.

Porcupine conchologist John Gwyn Jeffreys.[77] John Murray had initially been tasked with helping prepare the expedition's instruments, but he joined as a naturalist when a vacancy arose. He had studied at the University of Edinburgh and had seven months as ship's surgeon on an Arctic whaling ship under his belt, during which he made observations of the ocean, ice, and weather.[78] Physiologist and University of Edinburgh graduate Dr. William Stirling was slated to join the expedition, but when he demurred he was replaced by a last minute find: a young German named Rudolf von Willemöes-Sühm, whom Thomson met when the former landed in Scotland while part of the Danish Faroe Island Expedition.[79] In addition to John Young Buchanan, the expedition chemist cited in this chapter's opening, the scientific staff was rounded out by the addition of John James Wild, not a naturalist by training, who joined the expedition as official illustrator and Thomson's secretary. Moseley, Murray, and Buchanan would be elected to the Royal Society after their return, in 1877, 1896, 1887 respectively, as would Captain Nares and Lieutenant Tizard.

Though most of the scientists had at least some shipboard experience under their belts, they came of course from a vastly different background than the naval officers and crew, and this, as well as their differing goals for the trip, could be a point of friction, misunderstanding, and, most often, good-natured ribbing. This became apparent early on,

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[77] Joseph Foster, *Alumni Oxonienses: The Members of the University of Oxford, 1715-1886*, vol.3 (Oxford: James Parker & Co., 1891), 990. Accessed 20 May 2015. Online at https://archive.org/stream/alumnioxoniense01oxfogoog'page/n217/mode/1up/search/Moseley

[78] J. H. Ashworth, "Murray, Sir John (1841–1914)," rev. Eric L. Mills, first published 2004, 1838 words, with portrait illustration, *Oxford Dictionary of National Biography*. Accessed 20 May 2015. Online at http://www.oxforddnb.com/index/35/101035165/

[79] Rudolf von Willemoes-Suhm, *Die Challenger-Expedition: Zum tiefsten Punkt der Weltmeere, 1872-1876*, ed. Gerhard Müller (Stuttgart: Thienemann, Edition Erdmann, 1984), 14-15; Merriman, "Challengers of Neptune: the 'Philosophers'," Proc. R.S.E. (B) 72, 2 (1971/72), 22.

when the ship met rough weather for its first week out of England. Lieutenant Campbell described it as "a heavy gale, which shook us all nicely down into our places; close-reefed topsails—ship rolling like mad —sleep at a minimum—scientifics sick—stand up meals —crockery smashing—perfect misery—attempted joviality, &c."[80] Thomson, too, recognized the advantages of a "shakedown" cruise, at least in hindsight, for testing their arrangements for securing both men and equipment.[81]

Campbell's offhand remark about the "scientifics" being sick points to an interesting phenomenon about his reporting on the expedition; it is one of the few mentions of the scientific staff anywhere in his published account, which he assembled from letters sent home throughout the cruise.[82] When he did acknowledge their presence, he most often referred to them obliquely, conglomerated under the personification "science." When dredging must be done, or a beautiful bird shot and killed, it was "in the cause of science."[83] When specimens are not gathered, it "disappoints and dismays science."[84] Occasionally this masks variance in practice between the two staffs; when no animals are gathered in the trawling net near the Azores, "shore science theorizes that the trawl never touched the bottom, while naval practice swears that it must have done so."[85] It is not all friction, though, even in Campbell's account, as he also reports that the contents of any

[80] Campbell, *Log Letters*, 1.
[81] Thomson, *Atlantic*, Vol I, 60.
[82] Campbell left the ship in Valparaiso after receiving a promotion..
[83] Though clearly a sportsman, as someone of his gender and class would have been expected to be at the time, Campbell sometimes seems sympathetic to the scientific prey (though this is also occasionally tongue-in-cheek). Campbell, *Log Letters,* 33; 45.
[84] Campbell, *Log Letters*, 23.
[85] Campbell, *Log Letters*, 22.

given trawl becomes "a fruitful source of innocent betting" between officers and scientifics as the boredom of the long cruise starved both for entertainment.[86]

That good will and even respect were more usual between the two groups is apparent in Thomson's account, which is not to say the scientists did not endure the teasing anyone fresh from shore might endure aboard ship, "because [their] education ha[d] been sadly neglected in the matter of cringles and toggles and grummets, and other implements by means of which England holds her place among the nations."[87] Indeed, that the scientists were teased openly by officers and perhaps even crew suggests an ease and familiarity between the groups which boded well for their future cooperation. The scientists' appreciation for the naval officers is clear throughout their journals of the voyage, and as on the earlier voyage, they paid their respects in the naming of new species "whose discovery is due to the patience and ability with which they [the naval officers] have performed their task" of dredging the new specimens up; thus *Bathycrinus aldrichianus* was named after Lieutenant Pelham Aldrich, *Challenger*'s first lieutenant until he left with Nares for an Arctic expedition; *Hyocrinus bethellianus* recalled Lieutenant George R. Bethell; and *Pentacrinus maclearanus* honored ship's commander Captain Maclear.[88]

Despite the respect that the two teams obviously developed for each other, their duties and expectations for the voyage still varied, in part because of the backgrounds each brought to the ship. To officers who had had their fill of sea vistas over the course of a career, "exploring" meant landfall and trekking through the interior, yet Thomson made

[86] Campbell, *Log Letters*, 36.
[87] Thomson, *Atlantic*, Vol I, 114.
[88] Thomson*, Atlantic,* Vol I, 92; 123.

every effort to minimize time ashore from the beginning. Even when they reveled in the same accomplishments, they assigned different meaning depending on their point of view; when the ship was made fast to St. Paul's Rocks in the middle of the Atlantic, Lieutenant Campbell fetes it as unique accomplishment of naval skill, something no ship had done before. Yet the rocks' importance in Thomson's eyes lay in who had visited the location before, namely Charles Darwin and the *Beagle* in 1832, and Sir James Ross, on his way to explore Antarctic seas in *Erebus* in 1839.[89] The rocks thus became a touchstone for a different kind of legacy for each observer.

Of course neither sailing nor science took place onboard without two other groups of men, rarely mentioned in the accounts (and leaving few of their own). The first were the few scientific technicians aboard, such as the secretary/illustrator J. J. Wild. Thomson mentions him in his description of the ship's spaces as working with him in the fore cabin, but that is his only appearance in the account. Similarly, the corporal of Royal Engineers who was onboard as photographer for the first photographic expedition in history, Caleb Newbold, also appears only as an accessory, almost a piece of lab equipment, tied to the description of his workspace; his successors do not appear at all. The scientific validity of the expedition results, and their communication to and acceptance by other professionals relied on the illustrative capabilities of Wild's brush and Newbold's lens, as did the conviction in both public and government that the expedition had been worthwhile, yet the technicians responsible remained largely invisible. This held true after their return, when, despite publishing an account of their results before anyone else, Wild found little further work and eventually emigrated to Australia. Newbold and his first successor Frederick

[89] Thomson, *Atlantic,* Vol I, 100.

Hodgeson both deserted in the course of the voyage; what role their invisibility played in their decisions is impossible to say.[90]

Yet if the technicians, as in so much scientific work, remained largely invisible, the crew of the ship, who will have done the bulk of the actual work of rigging, hauling, and maintaining equipment under the officers' eyes, were even more so. The crew were, for one thing, the least likely to leave their own records of the voyage, while naturalists and even officers who had nothing to do with the official reports left memoirs and published their letters and journals.[91] Buchanan noted the importance of the usually invisible tasks of daily maintenance necessary to keep the expedition productive, pointing out that it was not simply luck that made the hemp sounding and dredging lines so ideal for the work;

> [o]n the contrary, deep-sea sounding-line must, to begin with, be made conscientiously and out the very best long-fibred hemp, and from the time it is first used until the day it is condemned as being worn it has to be most carefully attended to, especially in warm latitudes. After every sounding it has to be thoroughly dried before being used for the next one, and it has to be constantly surveyed in case of chafes or weaknesses. It was partly to the goodness of the material, but very much more to the unremitting care and watchfulness of those who had charge of it, that after the first beginning only one sounding-line was lost.[92]

Yet even here, the work is important but the workers invisible behind their pronoun. Thomson mentions the sailors but rarely, most notably on the two occasions when men were killed in the performance of their duties. When Buchanan recalled the "record of the 'Challenger' in freedom from accidents" as "a very brilliant one" he was not

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[90] Eileen V. Brunton, *The* Challenger *Expedition, 1872-1876: A Visual Index*, 2d ed. (London: The Natural History Museum, 2004), 7; 16.

[91] Of the crew, the one complete account is a modern edited volume of the letters of Joseph Matkin, found by his descendants over one hundred years later, *At Sea with the Scientifics: The* Challenger *Letters of Joseph Matkin*, ed. Philip F. Rehbock (Honolulu: University of Hawaii Press, 1992).

[92] Buchanan, "No. 2. A Retrospective of Oceanography in the Twenty Years before 1895. Address to the Oceanographical Section of the Sixth International Geographical Congress, held in London, 1895. [From the Report of the Sixth International Geographical Congress, held in London, 1895]," in *Accounts Rendered of Work Done and Things Seen*, 28-86 (Cambridge: Cambridge University Press, 1919), 49-50.

claiming that two accidental deaths in three and a half years at sea is an acceptable record; indeed, he is not talking about human beings at all. He means that *Challenger* lost to accident, over the course of the voyage, "nine sounding-lines . . . and with them thirteen thermometers. During the whole voyage only two temperature-lines were lost with eight thermometers."[93]

CHALLENGER AS RESEARCH VESSEL

Though the *Lightning* and *Porcupine* voyages had served as trial runs, allowing the scientists to hone their techniques and perfect their technologies for the grand expedition, *Challenger* was not in any way a finished result. The expedition remained on the cutting edge of ocean sampling technology, attempting feats of science at depths that had never been tried and with goals that evolved during the course of the expedition. That meant the technologies and their uses must evolve as well, and the naturalists' reports of their activities remained consciously evaluative. They repeatedly listed the advantages and disadvantages of their working arrangements at sea for the benefit of future endeavors, while at the same time insisting on the quality and precision of the work done onboard in order to validate the scientific claims they developed and the purity of their samples for work to be done ashore.

In addition to the fashioning of new spaces, existing spaces which retained their naval uses also acquired new meaning as they were assigned roles in the scientific process of collection, examination, processing, and preservation. In some cases these replaced usual, shore-based laboratory procedures, but the naturalists expounded on their suitability

[93] Buchanan, "Retrospective of Oceanography," 42-43.

for the role and the excellence of the results thus achievable. Often they insisted shipboard spaces and procedures in fact provided superior results or, as in the case of the photographic lab above, demonstrated the superior skills of the scientists and technicians, thus imbuing scientific claims made in unfamiliar and non-standard spaces with the authority granted by superior instruments and exceptional skill.

For botanists, for instance, dried plants were vital to send to institutions at home and abroad as specimens. They had brought aboard a "somewhat elaborate botanical press" for the purpose, only to discover that the air at sea, particularly in the tropics (and no doubt particularly on a steam ship, though they do not note this factor) is "constantly saturated with watery vapour." Happily they discovered an exceptionally dry, hot space in the funnel-casings where plants could be layered in bundles with sheets of botanical drying paper and wire ventilators and wrapped with cords. Two days of occasional cord tightening and the plants were properly and easily prepared, without even having to change the drying papers. So superior was this method that the elaborate press had been "entirely abandoned."[94]

The size of the ship, which had seemed such a boon on paper when compared to its predecessors, gave them qualms when first at sea, as they realized its different handling characteristics and the increased height above water from which the dredging must be handled changed the scale of the work. These issues were soon worked out.[95] One place in which the advantage of the larger ship became apparent was in *Challenger*'s capacity to carry several boats. Ship and boats used in combination could accomplish tasks on

[94] Thomson, *Atlantic*, vol 1, 18.
[95] Thomson, *Atlantic*, vol 1, 107-8.

different scales or through coordinated effort. When in port or at anchor, when the ship itself was at rest and the ability to work from it limited, the steam pinnace made an excellent shallow-water dredging platform. It was used almost daily in the seven to twenty fathom waters off Bahia, for instance, "bringing up large numbers of fine tropical shore forms."[96]

The boats also came in handy for current measurement, a tricky problem which *Challenger* made great inroads towards solving. One method was to anchor the boat itself, allowing the measurement of surface or sub-surface current from a fixed point much closer to the water's surface than the ship's deck.[97] Another technological solution to sub-surface current measurement was to anchor a buoy, fix its position astronomically, then set adrift another buoy with a large current drag suspended by wire the desired depth below it. The ship was thus free to follow the drift-buoy, which, little affected by the wind or current due to its little freeboard or sail area, would be carried by action of the subsurface current on the drag below, and mark its position over time. This system remained imperfect, but Buchanan's assertion that if currents continued to be studied seriously he had "no doubt that the best instrument will develop itself in the work" displays a technological optimism both typical of scientists of his era and representative of his interpretation of the *Challenger* experience.[98] Tools would continue to "develop themselves" to fit the work because that method of modification to meet necessity had worked for them so well thus far.

[96] Thomson, *Atlantic*, vol 2, 144.
[97] Buchanan, "Retrospective of Oceanography," 84.
[98] Buchanan, "Retrospective of Oceanography," 84.

Already off the coast of Portugal, in the instance with which this chapter opened, they had tinkered with the mechanism for closing and hauling in the dredge until they had arrived at a method of using a weighted traveller which, while it lengthened the time required to lower the dredge, eliminated the problems previously encountered with the dredge and dredge line becoming entangled. When the tremendous hauls of "ooze" from the bottom, initially so celebrated, became monotonous and the naturalists feared they were missing "the higher groups" of life forms, "it was proposed to try the ordinary trawl." This successfully gathered larger invertebrates and fish and soon became a standard method, especially in very deep water where a smooth bottom was expected. The trawl's design did not remain "ordinary" either, but was soon modified into a "deep-sea" version.[99] The trawl did not completely replace the dredge, however; each was modified to perform a more specialized function and seen as more useful at certain depths, in certain conditions, or for the pursuit of certain specimens. For instance, a series of trawl failures near the end of the voyage, in March 1876, prompted a return not to the clunky, original dredge but to "a large light dredge which we had had made at Hong-Kong for the shallow-water sponge-producing seas of the Philippines."[100] A tow-net, too, was "constantly worked" between the surface and one hundred fathoms.[101]

Often, the scientists' memories of their work on *Challenger* contain an apparently contradictory list of the advantages and disadvantages inherent in such a research platform. Most obviously, ships are not stable in the best of circumstances, and in bad weather they

[99] Thomson, *Atlantic*, vol 1, 67-9.

[100] Even then, it "came up with scarcely any ooze and with only a small number of animal species," Thomson, *Atlantic*, vol 2, 256.

[101] Thomson, *Atlantic*, vol 1, 70.

are instability incarnate. "Ship-life is generally unfavorable to steady work," Thomson noted, "and during a great part of the time the motion of the ship makes it impossible to have even the limited space at one's command in his cabin, littered with papers and journals and memoranda in the orderly confusion which is inseparable from comfortable literary work."[102]

Some of these problems were solvable via ingenuity, such as with gimbaled equipment, and with experience, such as learning to secure glassware for sea, or to time a measurement with the rhythmic motion. Still, Thomson complained of numerous opportunities missed because of "boisterous" weather resulting in lost specimens or complete inability to deploy equipment.[103] In very deep water, these difficulties were magnified many-fold by the sheer lengths of line involved and the time required to lower and raise it.[104] "Jerks" caused by inept handling of the line or sudden motion of the ship caused thermometer indices to move slightly, and "an observation [wa]s in this way very frequently vitiated." [105]

Steam propulsion solved some problems while creating others. Deep sea dredging would have been impossible without the ability to move in a desired direction at a fairly constant rate, unbeholden to variable winds, or to maintain position against wind and current. The steam-powered donkey engine made the hauling up of literal miles of dredge line possible, an otherwise back-breaking task for the crew in shallower water and

102 Thomson, *Atlantic*, vol 1, v.
103 For examples, see Thomson, *Atlantic*, vol 1, 237, 254; vol 2, 186, 205, 219
104 Thomson, *Atlantic*, vol 1, 329.
105 Thomson believed this problem of the unpredictable inaccuracy of individual readings could be solved by the aggregate of "a series of corroborative determinations." "[I]t is wonderful in a series of such curves how strong the internal evidence is of their accuracy," *Atlantic*, 303-4; 308..

probably impossible at mid-ocean depths. Yet exploring the abyss thus depended upon coal, and the ship's coal-carrying capacity depended upon space. *Challenger* carried 230 tons in coal boxes, and could manage another 50 tons in bags on the main deck (which would be both filthy and inconvenient).[106] When this supply was depleted, the ship became again a sailing vessel, unable to do most of its scientific tasks, nor even to reach port if the weather did not cooperate.[107] The ship's propeller posed a potential threat to gear lowered over the side, too, as when a "sounding-line with seven thermometers attached fouled the propeller and was carried away."[108] Yet the well in which the propeller normally rode served the naturalists as a window into the depths when it was retracted.

Overall, the naturalists claimed the ship's advantages outweighed any disadvantages, especially in hindsight. Compared to an iron ship, which would have been heated through the day and cooled only slowly at night, the thick wooden hull kept the interior a fairly constant temperature, conducive not just to the comfort of the naturalists but to the reproducibility of tests, an important factor in the naturalists' claims to the validity of their results. The light and ventilation provided by the large former gun-ports was another advantage. Buchanan even suggested wooden ships would be preferable to shore bases in the tropics, a choice which might not appear obvious to those without field experience.[109]

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[106] *Challenger* Ship's Log, 15 Nov 1872 to 1 Feb 1874; ADM 53-10536; TNA. Using this coal, of course, required more back-breaking, dirty, and dangerous labor, this on the part of another the ship's engineers, another group invisible in the scientific records.

[107] Such as in September 1873, when with coal "almost entirely expended, the engines were stopped, and . . . we crept along toward Bahia under all plain sail," Thomson, *Atlantic*, vol 2, 121.

[108] Thomson, *Atlantic*, vol 1, 396.

[109] Buchanan, "Retrospective of Oceanography," 36; 40.

CONCLUSION

Buchanan's assertion of experiential expertise went hand-in-hand with his description of technology as self-developing in response to requirements. In each case, the resulting knowledge, or the instrument with which to derive knowledge, is intimately enmeshed in the physical reality of the sea. Such knowledge carries an inherent claim to authority which allowed the naturalists to relate their discoveries as truth, and their process and field of endeavor as universally applicable to the oceans, and thus as the basis for a new science.

Not least of the technologies which both naturalists and naval officers actively adapted and created to access the ocean bottom was their ship itself. The naval officers—both on board and ashore—did not intend the redefinition of their ship into a new class; they made the accommodations they did in order to fulfill their mission, which was simply one in a series they would undertake over their sea-going careers. While participation in that mission granted the ship a certain historical status (mostly, again, in terms of superlatives accomplished) and them a part in it, it remained HMS *Challenger*. The naturalists, on the other hand, had little initial sense of the warship as more than an iconic image; even those with some expeditionary experience had known a ship or two, but only over a fairly short term and as passengers, and mostly in terms of how it and its operations could—or failed to—be modified to meet their needs. They did not envision their goal in terms of mission accomplishment, but in terms of scientific accomplishment. Thus they molded *Challenger* and its spaces and equipment against another model, that of the shore-based laboratory. The ship's spaces and equipment must thus become not only useful, but precise and accurate, a location of knowledge production equal to or even better than its shore-based counterparts, in order to grant their knowledge claims similar authority. Between these two groups, they made of *Challenger*, moreso than its predecessors, a new kind of ship. Whether the expedition marked the birth of oceanography remains debatable; that it marked the birth of the research vessel is likely.

Each group tinkered at the same time with their sense of their own identity. The scientists, in making claims to the authority of the ship as laboratory, staked their own claim to authority based on their experience aboard. In this they participated in an established trope of field scientist as hero, but they also claimed that trope as oceanographers' own. Many of the naval officers, too, experienced a shift in their own self-definition. This is not to say they lost their sense of themselves as naval professionals, but several participated in ongoing research and maintained correspondence with their naturalist colleagues in the decades that followed the voyage. This subtle shift in their own status was acknowledged by the election of several of their number to fellowship in the Royal Society. Together, then, the two sets of professionals forged a bond upon which ocean science would depend for access to the deep sea going forward, though that bond, reliant as it was on naval vessels and crews, established as well a precedent that left those without government sanction, including women, stuck ashore

CHAPTER 3: The Oceanographic Yachts of Prince Albert I of Monaco

> *When navigators who ply the sea, understanding the usefulness of oceanographic research, which is easy to do, will want to devote to them some of the leisure hours which are never absent from a long journey, many doubts will be clarified, many gaps filled in zoology, and the sailors will gain, with the votes of the masters of science, their place in the midst of that phalanx which opens such vast horizons to the human mind.*
>
> -- Albert I of Monaco[1]

In 1884, Albert Honoré Charles Grimaldi, thirty-five-year-old heir to the tiny Mediterranean principality of Monaco, attended a presentation in Paris on recent French oceanographic research, a still-propagating ripple of the *Challenger*'s passage a decade earlier.[2] The British expedition had been avidly watched by scientists and the populace at home, prompting frequent reference in popular publications as diverse as *Popular Science Monthly* and *Punch*.[3] Authorities abroad followed it as well, almost certainly recognizing the unprecedented scale of the effort as a display of scientific imperialism designed to reinforce the British claim to superpower status. Several countries, inspired or concerned by the expedition, or both, launched their own vessels to do science on the deep sea. Indeed, while the expedition was still underway, the Germans founded what would become major oceanographic institutions in Wilhelmshaven and Hamburg, and sent the *Gazelle* on

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[1] Albert Ier, Prince of Monaco, "Campagne de 1884 (Baltique)," *Amis du Musée Océanographique de Monaco* 13 (January 1950) : 1-2.

[2] Indeed, so closely is the *Challenger* tied to Albert that Jacqueline Carpine-Lancre and Luiz Vieira Caldas Saldanha report an "erroneous 'tradition'" that Albert was in Lisbon at the time of *Challenger*'s January 1873 visit (he was in fact in Paris); they point to John Young Buchanan's presentation at a 1903 conference at the Royal Institution in London as the origin of this myth. Carpine-Lancre and Saldanha, *Dom Carlos I, Roi de Portugal ; Albert I^{er}, Prince de Monaco : Souverains océanographes* (Lisbonne: Fondation Calouste Gulbenkian, 1992), 17,20.

[3] See, for instance,"How the Sea-Depths Are Explored," *Popular Science Monthly* 3, July 1873: 257-269; T[homas] H. Huxley, "The Problems of the Deep Sea." *Popular Science Monthly* 3, August 1873: 206-210; ibid., "On Some of the Results of the Expedition of HMS Challenger," *Popular Science Monthly* 7, May 1875: 26-46; "The Challenger Her Challenge," *Punch* , 14 December 1872, 245; "All Around the World," *Punch*, 21 December 1872, 257; "First News of the Challenger," *Punch* , 18 January 1873, 30; "Man to Man," *Punch*, 10 July 1875, 12.

its own scientific—and imperial—circumnavigation.[4] *Challenger* also interacted with data obtained almost simultaneously by the American naval vessel USS *Tuscarora* in the Pacific, though not with the actual vessel or personnel.[5] American scientist Alexander Agassiz apparently visited *Challenger* in Halifax, then made several collecting cruises in the Atlantic between 1877 and 1880 in the US Coast Survey steamer *Blake*.[6] In Norway, Georg Sars, whose work had played a part in spurring the British to action, in turn pointed to *Challenger* to justify North Atlantic expeditions in the *Véringen* in the later 1870s.[7] The French reaction was slower and more circumscribed, in both scope and budget; two ships, the *Travailleur* and the *Talisman*, performed four oceanographic summer cruises in the North Atlantic in the early 1880s.[8] Again following the *Challenger* example, the results of these efforts were published in seven volumes over the ensuing twenty years, and

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[4] The institutions were the Kaiserliches Marineobservatorium, or Imperial Navy Observatory, founded in 1874, and the Deutsche Seewarte, or German Marine Observatory, founded in 1875. Wolfgang Schott, *Early German Oceanographic Institutions, Expeditions and Oceanographers*, (Hamburg: Deutsches Hydrographisches Institut, 1987), 3.

[5] Buchanan, "No. 2. A Retrospective of Oceanography in the Twenty Years before 1895. Address to the Oceanographical Section of the Sixth International Geographical Congress, held in London, 1895. [From the Report of the Sixth International Geographical Congress, held in London, 1895]," in *Accounts Rendered of Work Done and Things Seen*, 28-86 (Cambridge: Cambridge University Press, 1919), 50.

[6] On Agassiz's visit, see Philip F. Rehbock, ed., *At Sea with the Scientifics: The Challenger Letters of Joseph Matkin* (Honolulu: University of Hawaii Press, 1992), 384n20; Dean Allard, "The Origins and Early History of the Steamer Albatross, 1880-1887," *Marine Fisheries Review* 61, 4 (1999): 3.

[7] While Sars and his collaborator H. Mohn invoked the *Challenger*, they pointed specifically to the *Porcupine*, "which bore a true pioneering character," as a more appropriate (and affordable) model for Norwegian science. Memorial presented to the Norwegian Government by Professors H. Mohn and G. O. Sars in March 1874, in C. Wille, "Historical Account," *Den Norske Nordhavs-Expedition 1876-1878* (Christiania, 1882), 1-9, quote on p. 6.

[8] [Léopold Alexandre Guillaume] Folin, *Sous les mers: Campagnes d'explorations du "Travailleur" et du "Talisman"* (Paris: J.-NB. Bailliére et fils, 1887). For the expedition results, see A. Milne-Edwards, ed., *Expéditions scientifiques du Travailleur et du Talisman pendant les anne ́es 1880, 1881, 1882, 1883,* 7 vols in 8 (Paris: 1888-1906).

the researchers made an effort to engage the public's interest, including by presenting them at the Muséum d'histoire naturelle de Paris in 1884.[9]

As a teenager, Albert had trained and served as an officer of first the Spanish and then the French navies—a not-uncommon course for the future heir to a tiny principality without a naval force of its own. By 1884 he remained a sailor by avocation, with a decade and a half's experience at sea on warships and yachts. The *Travailleur* and *Talisman* results inspired a sudden and forceful interest in wresting knowledge from the deep that would provide a focus for his time at sea and much of his philanthropy at home for the next forty years of his life. Albert would almost immediately begin to use his yachts as a platform for conducting research at sea. Just as quickly his conception of the possibilities for understanding the oceans grew to encompass ever increasing fields of inquiry. Throughout, he understood the need to develop tools to meet the specific needs for each new facet of research, and he sponsored and even designed a broad array of technologies, up to and including a series of new yachts to accommodate them.

As personal yachts, the Monagasque research vessels constitute a completely novel picture of science at sea, in terms of size, patronage, and scope. If the *Challenger* experience had differed widely for scientist, officer, and crewman, that onboard the yachts was simultaneously more intimate and more rigidly divided by class, status, and education. Yet these vessels and their equipment followed a similar path, through iterations of design and reinvention, while their designers revised as well their perceptions of the sea, of their potential to discover its secrets, and of its potential to serve human needs. With each new

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[9] Jacqueline Carpine-Lancre, "Le Prince Albert I[er] de Monaco marin et océanographe: chronologie sommaire," *Océanis* 19, no. 4 (1993): 122. Hereafter "Chronologie sommaire."

ship, Albert added space and capability, yet in each case within years he would bemoan the need for more of both. He was outfitting ships in an age of generalization, when a ship could still be expected to carry the equipment for an omnidisciplinary examination of the sea in all its complexity. The scientists he invited aboard, though, had begun to specialize. Perhaps begun with Buchanan's identification as chemist, in opposition to the naturalists, in *Challenger*, this specialization would continue as the scope of ocean science began to approach that of the global ocean itself, and no one researcher could apply himself fruitfully to all of it. In many ways an old-fashioned gentleman-naturalist, Albert served as a key patron to the ocean science done on his ships and in the shore-based institutions he endowed to work with them. This gave him an important, if perhaps slightly ironic, role in the ongoing creation of professionally trained oceanographers.

LAUNCH

Born in Paris and classically educated there and in Orléans, Albert began his encounter with the oceans in the fall and winter of 1865, when the then-seventeen-year-old began training as an officer of the imperial French navy at Lorient.[10] The following year, he joined the Spanish navy, where he served out of Cadiz and in the Caribbean in the ranks of ensign and then lieutenant de vaisseau. He left Spanish service out of loyalty to class

[10] This summary of Albert's career relies heavily upon Carpine-Lancre, "*L'Hirondelle* aux Açores," *Açoreana,* Suplemento (1992): 22-49; and Carpine-Lancre, "Chronologie sommaire," 121-135. Albert published an autobiography in Monaco in 1902 as *La carrière d'un navigateur*. Numerous reissues have appeared since. Recent editions include *La carrière d'un navigateur* (Monaco: Éditions des Archives du Palais Princier, 1966), which includes a short introduction by Jacques-Yves Cousteau, then director of the Musée Océanographique in Monaco, which Albert founded; and *Mémoires d'un navigateur* (Paris: Presses de la renaissance, 2006), a reprint of the 1951 edition, which includes a lengthy preface by Albert II of Monaco, current sovereign of the principality and his namesake's great-great-grandson.

when the Spanish Queen Isabella II was deposed and exiled in 1868.[11] Albert returned home, but he kept his hand in by sailing the Mediterranean coast in a small cutter, pointedly named *Isabelle II*, and in 1870 offered his services to France in their war with Prussia. He served aboard *la Savoie* and *la Couronne*, but the war was short and largely conducted on land.

Albert was restless, no doubt in part due to his problematic personal life. His arranged marriage to Lady Mary Victoria Hamilton, whom he had met just one month before the nuptials, never gelled; the new princess disliked Monaco, the Mediterranean, and, presumably, Albert himself. Although their son Louis, Albert's eventual heir, was born within a year, Mary took advantage of Albert's absence during the Franco-Prussian War and returned home. She never returned to Monaco, though a civil divorce and Catholic annulment would take ten more years. In the interim, Albert was likely unhappy trapped ashore as a subject of gossip. Yet his little cutter, while sufficient for Mediterranean coastal sailing, was neither safe nor comfortable for long voyages on the open ocean. He petitioned his father, Monaco's sovereign Prince Charles III, for permission—and funding—to go to England to acquire a larger, better equipped vessel. Charles was unenthusiastic; a yacht would be a major expense, one that would require significant outlay of capital up front, but also major recurring costs both in terms of maintenance and repair and in order to pay the crew required by a vessel of its size and the staff required by Albert's rank. This would constitute almost the entirety of the younger prince's annual personal income. Charles also doubted his son's commitment to such a project, probably recognizing its origins in Albert's "exceptional and painful" personal

[11] Albert, *La carrière d'un navigateur*, 2d ed. (Monaco: Imprimerie de Monaco, 1905), 41.

situation. Albert remained committed, though, insisting that he wished "to turn his thoughts to the maritime work and research which had always interested him, and ha[d] become for him an imperative need." Charles at last gave in.[12]

Albert travelled to England to purchase a 200-ton, 32-meter long, wooden, schooner-rigged sailing yacht, built in 1862 at Camper and Nicholson's Gosport yard, which he renamed *Hirondelle* (Swallow).[13] Despite his avowed interest in research, he did not yet have a particular program in mind, and this ship was equipped as a pleasure yacht. *Hirondelle* was powered solely by the wind, and its systems solely by the muscle-power of its fifteen crewmembers. Nevertheless, it remained a capable ocean-going yacht, in which Albert and his associates would weather at least one hurricane in the years ahead. Albert diligently maintained his ship, and he modified and upgraded its equipment frequently, balancing his desire for the state of the art with his father's accurate summation of the financial drain involved. Already in 1875 he had the ship's tiller replaced with a wheel-controlled rudder, allowing finer course control with fewer hands.[14]

Whatever Albert had meant by research when petitioning his father for the yacht, he spent the first ten years of his ownership cruising the Atlantic and Mediterranean,

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[12] Albert, untitled memorandum, Paris, 1 September 1873, "Yacht l'Hirondelle Comptes d'Acquisition, 1873," folder C812, Archives du Palais Princier, Monaco [APM]. Carpine-Lancre suggests father and son had held a similar conversation in 1865, when Albert had had to convince his father that his desire to become a sailor was not "a caprice of adolescence"; Carpine-Lancre, "L'Hirondelle aux Açores," 24. Throughout, quotation from French language titles are translated by the author; Albert wrote for English language titles in English, so quotations from these titles are direct.

[13] Jules Richard, *Les campagnes scientifiques de S.A.S. le Prince Albert Ier de Monaco*. *Exposition Universelle de 1900* (Monaco: Imprimerie de Monaco, 1900), 7 ; Carpine-Lancre, "Chronologie sommaire," 121-122. Documents from the yacht's later resale list it at 187 tons and 32.18 meters, "Renseignements concernant le Yacht 'Hirondelle'," n.d., folder C819, APM. A "schooner-rigged" vessel has its largest sails aligned forward and aft (as opposed to a port-starboard alignment) on two or more masts. To the unschooled observer, they will appear more triangular rather than square, though the ship may carry smaller square sails above the mainsails.

[14] Christian Carpine, *La pratique de l'océanographie au temps du Prince Albert Ier* (Monaco: Musée océanographique, 2002), 19.

voyages he would later describe as "instructive, of course, but without general utility."[15] In 1884, though, newly inspired, whether by the possibility of pursuing research at sea or by the desire to join the community of researchers already publishing on it, Albert dedicated a portion of the time during a July to September cruise of the Baltic making observations. Not yet systematic, the cruise was also never reported to the scientific press, as his campaigns would be beginning the following year. While Monagasque historian Jacqueline Carpine-Lancre suggests this is because any samples taken were lost, Albert did write a report of the trip, as he would his later ones.[16] In it, he described observations on marine fauna, both with the normal equipment of a gentleman's yacht, such as binoculars, as well as with a bottom trawl, noting a paucity of seabirds and bottom fish in the Baltic. This went beyond mere list-making; Albert posited geophysical explanations, citing salinity and current as probable causes. More research into the lifecycles of fishes, he suggested, would aid in understanding the laws which governed water circulation.[17] This sense that an understanding of one aspect of the sea would lead to a greater understanding of the next was central to Albert's iterative approach to studying the oceans.

THE PROGRESSIVE STUDY OF THE SEA

By the following summer, he had developed a more comprehensive program, and had done so in concert with professional scientists in Paris. In collaboration with Parisian

[15] Albert, [Campagne de 1885], manuscript, cf. 22 v° f. 23 v°, Archives du Musée Océanographique de Monaco [AMOM], Cahier A, quoted in Carpine-Lancre, "L'Hirondelle aux Açores," 32.

[16] Carpine-Lancre, personal communication, 1 September 2014.

[17] Albert's report, the source of the epigraph which began this chapter, was discovered in the archive and published in 1950 as Albert, "Campagne de 1884 (Baltique)," 1-3.

naturalist and professor of comparative anatomy Georges Pouchet, who had funding from the Municipal Council of Paris, Albert developed a plan to study the currents of the North Atlantic on a grand scale. Over the next three years, with Pouchet and alone, Albert designed, tested, and launched a series of floats into the waters north and west of the Azores and east of Newfoundland. Albert tried three different models of float constructed of glass, wood, and metal, and he attempted to weight them to minimize the effects of wind, and to compensate for the slow accumulation of marine growth they would endure over time at sea. Each bore a distinct number and a message instructing finders to relay details of the float's recovery to the prince via diplomatic channels; Albert's title and high profile encouraged the cooperation of both fisherman and diplomat.[18] In late July 1885 Albert and his crew worked 31 and one half hours straight deploying 180 floats at intervals along a 110-mile line west of the Azores. Further float deployments followed in the subsequent summers, with floats numbered in a continuing sequence. Thus when a specific numbered float was found, Albert could pair the details of its recovery with those of its launch, allowing him to calculate trajectory and approximate speed of the currents to which it had been subjected. Though subject to numerous inaccuracies for any given buoy, in aggregate the data gave Albert a detailed picture of the Atlantic current system and allowed him to describe the circulation later known as the North Atlantic Gyre. To Albert, this knowledge was fundamental to further study of ocean zoology, as one must understand the

[18] Albert, "Sur une expérience entreprise pour déterminer la direction des courants de l'Atlantique," *Comptes rendus des séances de l'Acadèmie des Sciences*, 16 November 1885, reprinted in *Résultats des campagnes scientifiques accomplies sur son yacht*, f. 84 (1932): 2-4 ; Albert, "Expériences de Flottage sur les Courants Superficiels de l'Atlantique Nord," Congres International des Sciences Geographiques en 1889 (Paris : Sociéte d'Éditions Scientifiques, 1890), reprinted in *Résultats des campagnes scientifiques,* f. 84: 121-128 ; Albert, "L'Outillage moderne," *Résultats des campagnes scientifiques,* f. 84. See also "Georges Pouchet [obituary]," *New York Times*, 14 April 1894.

place to explain its inhabitants. It proved to be of more concrete and pragmatic value in the aftermath of World War I, when Albert's ocean current work allowed him to predict the likely tracks of free-floating mines still loose upon the Atlantic.[19]

While Albert took samples with nets during this expedition, and indeed had used a bottom trawl during the preliminary 1884 expedition, he saw his investigation as a progressive program, one that allowed him to develop increasing information about the oceans in a step-by-step fashion. He had begun with surface currents because of their perceived fundamentality to so many other areas of ocean science: they were of clear importance to sailing ships; they explained the movement of animal life, especially eggs and larvae, and the transport of ice and debris; and their principles underlay many of the phenomena of meteorology and climatology.[20] Once he felt he had a thorough understanding of these currents, he added the study of sub-surface currents using vertical temperature and density series taken with the Miller-Casella reversing thermometer and a sampling bottle designed by his long-time collaborator Dr. Jules Richard, who headed his shipboard laboratory and would become first director of the Musée Océanographique.[21]

Albert's oceanographic reach soon exceeded *Hirondelle*'s grasp. For the kind of work Albert increasingly wished to do, the schooner was too small, and while sail power meant their time at sea was not limited by the availability of coal, it also meant research

[19] Albert, "Marche des mines flottantes dans l'Atlantique Nord et l'océan Glacial," *Comptes rendus de l'Académie des Sciences*, 23 Dec 1918; also printed in *Bull. Inst. Océan*., no. 357 (5 Aug 1919). Reprinted in *Résultats des campagnes scientifiques*, f. 84: 135-139.

[20] Albert, "Les Progrès de l'Océanographie," conférence faite à la Sorbonne, 14 Jan 1904, pour la Société des Amis de l'Université; *Revue Scientifique*, 6 Feb 1904, *Les cahiers de l'Université populaire,* t. 1, no. 2 (10 Feb 1906) : 49-57, and *Bull. Musée océanographique de Monaco,* no. 6 (20 Feb 1904); reprinted in *Résultats des campagnes scientifiques*, f. 84 (1932), 209. Since Prince Albert published several works by this title, hereafter each will be differentiated upon second mention by date.

[21] Albert, "L'Outillage moderne," 198-206.

was done at the mercy of the wind.[22] The ship could not remain in a precise location at sea—in order to tend a trap, for instance, or take a sounding—in anything but the calmest weather. Neither could it chase a whale (or later, a weather kite or balloon) nor tow a trawl or net unless the winds were fortunate.

Steam power had also been vital to *Challenger* and its peers' ability to reach the deepest depths, as their auxiliary "donkey" engine could be used to haul in a heavy line. Since *Hirondelle* relied upon muscle power—meaning some portion of his fifteen-man crew would take it in turns to walk around the capstan which slowly winched in the line—the process was exceptionally slow. While *Hirondelle*'s crew trawled at depths up to 2870 m, Richard would later report, lowering the equipment by hand took three hours eighteen minutes, and raising it nine hours thirty minutes, thus requiring almost thirteen hours for one use of the trawl; under steam the entire process would require less than five.[23] *Hirondelle* had also never been intended for scientific work, so it had no designated laboratory space; instead the salon had had to be sacrificed for the purpose. Scientist he might be, but Albert was still a prince and thus a gentleman, and the salon was no doubt missed.[24]

Albert's personal circumstances also changed drastically in September 1889, when he succeeded to the throne of Monaco upon the death of his father, Charles III. The effect

[22] Albert, "Recherche des animaux marins. Progrès réalisés sur l'Hirondelle dans l'outillage spécial," *Comptes rendus des séances du Congrès international de Zoologie de Paris*, 1889 : 133-159; reprinted in *Résultats des campagnes scientifiques*, f. 84, 178.

[23] Richard, *Exposition Universelle*, 7-8.

[24] In October 1898, supplies remaining aboard **after** the summer's expedition included a three-page list of wines and spirits (168 bottles of red table wine, fifty-one of Moët & Chandon, nine of Scotch Whisky, ten of Black Forest kirsch, three kinds of Madeira); while this was for the much larger *Princesse Alice* (II), it is indicative of the prince's expectations for life at sea, "Inventaire des Vins et Spiritueux restant à bord au 24 Octobre 1898," folder C851, APM.

of this new role on Albert's personal role in oceanographic work would be mixed. While as sovereign prince, he had a freer hand with his budget and no need to seek permission for future yachts, he now had responsibilities ashore which would limit his time at sea to a few months a year at most. In October, Albert remarried, another change in circumstance which would no doubt make further claims upon his time.

Thus empowered, Albert contracted in March 1890 with shipbuilders R. & H. Green of Blackwall, London, for a new yacht, which he would name *Princesse Alice* after his new wife, Marie Alice, née Heine, the young, American-born widow of the Duke of Richelieu.[25] The *Hirondelle* was sold, and in the meantime Albert rented a steam yacht to conduct research for the 1890 season, though he stayed in the vicinity of Monaco.[26]

Princesse Alice was a three-masted auxiliary steam schooner of composite wood and metal construction. The new yacht's 52 m 60 length overall and 650-tons displacement were vast improvements over its predecessor (and at 3 m 75 draft, it barely drew more water than *Hirondelle*, allowing it to work in fairly shallow as well as deep water). Albert chose to retain the sails "in order to preserve as much space as possible for . . . engaging in serious scientific work, combined with the wants of social family life." (It seems he had missed that salon!) The engine-room, which thus remained small enough to be tended by one man, held the 350-hp steam engine, as well as a fresh water distillation unit—a handy piece of equipment but not a novel one; *Challenger* too had carried a

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[25] Articles of agreement between His Serene Highness the Prince of Monaco and Richard and Henry Green Shipbuilders of Blackwell, 21 March 1890, folder C821, APM.

[26] "Renseignements relatifs à l'Equipage du bateau à Vapeur Amphiaster," 24 Feb 1890, folder C820, APM; Carpine-Lancre, "Chronologie sommaire," 123.

distilling unit—and an electrical generator.[27] Electric lighting had been tried aboard ship as early as 1880, and scientists quickly recognized its usefulness for extending the available workday at sea.[28] The US Fisheries vessel *Albatross*, built in 1882 and often touted as the first large, purpose-built ocean research vessel in the world, carried an Edison dynamo powered by an Armington & Sims engine, and by 1890 dynamos designed specifically for shipboard use were available on the commercial market.[29] *Princesse Alice*'s generator powered one hundred interior lights as well as three bright exterior lights to permit nighttime work on deck and a 10,000-candle search light to illuminate the sea for night work with boats or buoys.[30]

Another state-of-the-art piece of equipment in the engine room was the ammonia freezing-machine. Shipboard refrigeration had been attempted via natural ice and forced air circulation for decades, and with a refrigerating machine along modern lines as early as 1879.[31] *Princesse Alice*'s system worked by liquefying ammonia to supercool brine which was then circulated through tubes in the refrigerating chamber. Objects to be frozen were placed within in protective molds, then moved to a chamber kept cold by a coil of ammonia pipes near its roof, where their temperature could be maintained. While refrigeration certainly benefitted Albert's dining table, it was also a key component in the new ship's purpose-driven design. The refrigerating chamber itself was in the ship's central laboratory, and the cold chamber directly below in the ship's hold.

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[27] Richard, "Exposition Universelle," 8; "Renseignements concernant le Yacht 'Hirondelle'," n.d., folder C819, APM. Albert, "A New Ship for the Study of the Sea," *Proc. Roy. Soc. Edinburgh*, 1891 : 295-302; reprinted in *Résultats des campagnes scientifiques*, f. 84, 196.

[28] Anonymous, "The Columbia," *Scientific American* 42, 21 New Series (22 May 1880): 326.

[29] Allard, "Origins and Early History," 6, 12; Carpine, *La pratique*, 6.

[30] Richard, "Exposition Universelle," 8; "Renseignements concernant le Yacht 'Hirondelle'," n.d., folder C819, APM; Albert, "New Ship, 196.

Refrigerating liquid was also piped to nearby laboratory tables "to be used in the delicate biological experiments."[32]

This was one of three separate laboratories onboard. The first was on deck, just behind the main mast, where samples could be dealt with immediately as they were hauled onboard. Once sorted and cleaned, biological samples travelled via lift to the central laboratory with its refrigerated tables; this lift also provided communication with the cold chamber below. Oceanographic (non-biological) samples went to a chemistry and physics laboratory aft. Skylight provided light during the day, and each lab was set up to allow four or five people to work simultaneously, and heated by steam radiators in cold weather.[33]

During seven annual campaigns between 1891 and 1897, the ship conducted operations as deep as 5530 meters. The first—a short, one-month cruise that served as a sea trial in early fall 1891—conducted operations in only five discrete locations. These specifically identified sites of scientific scrutiny at sea, at which several variables across multiple water depths would be examined simultaneously or in sequence, were already beginning to be called "stations"; Albert made a practice of anchoring a buoy to mark the spot when possible and conducting both biological (which he called zoological) and physical (which he called "pure oceanographical") work at each station.[34] It was 1894 before he was able to conduct a complete zoological and oceanographic campaign on the

[31] The Anchor Liner *Circassia* successfully maintained the temperature of pre-chilled beef and mutton on a voyage from New York to England in 1879, James T. Critchell and Joseph Raymond, *A History of the Frozen Meat Trade* (London: Constable, 1912), 336-7.

[32] "[T]he cold chamber is large enough to accommodate a part of the ship's provisions," Albert, "New Ship," 196.

[33] Albert, "New Ship," 196.

[34] Albert seemed to believe he had coined the term, "L'Outillage moderne," 203.

new ship, but he reported that those of 1892 and 1893 were "not unfruitful." During these years he conducted operations in the Mediterranean, the Strait of Gibraltar, the Gulf of Gascoyne, and off the western coasts of Morocco, Portugal, and Spain. He was aided onboard by John Buchanan, of earlier *Challenger* fame, who analyzed the density and alkalinity of water samples both onboard and back in his own lab in Edinburgh. In inviting Buchanan aboard and then reporting that this work confirmed earlier work by Gwyn Jeffreys and Carpenter, Albert explicitly portrayed his expeditions in continuity with *Challenger*'s epic voyage.[35]

In addition to Richard, who was a regular and usually described as chief of his zoological lab, Albert invited a range of other European experts to join him on these expeditions. Some made multiple trips. As had his predecessors, he also provided samples and information to shore-based scientists for analysis. After almost every trip Albert reported personally to the Académie des Sciences in Paris on their preliminary results. With the help of his network, Albert kept actively abreast of innovations in equipment and instrument design, corresponded with practitioners with their own design ideas, and frequently (and successfully, by all reports) implemented his own design ideas to address perceived problems, either with existing equipment or with a lack of equipment to address new questions. These technological innovations he also reported to the Académie, always careful to provide proper attribution of each new idea. Each new campaign was more fruitful than the last, he said, not only because the ship had been designed to purpose, but "because the amenities of my ship, each time augmented,

[35] Albert, "Sur les premières campagnes scientifiques de la *Princesse Alice*." *Comptes rendus de l'Académie des Sciences,* 7 Jan 1895. Reprinted in *Résultats des campagnes scientifiques accomplies sur son yacht*, f. 84 (1932): 12-15.

modified by experience, now allow the *Princesse Alice* to undertake things that were previously inaccessible."[36] Each of his expeditions also included an artist, a common expedition team member even after the advent of photography, as a trained scientific illustrator could capture not only the form, but the vibrant colors of captured creatures, which fade especially quickly in marine fauna even before they are subjected to preserving fluids.[37] Indeed, the yacht's provision of facilities for social guests as well as scientific meant Albert saw no bar to inviting Mademoiselle Jeanne Le Roux, "artiste peintre," to accompany the *Princesse Alice* to the Azores on the yacht's third expedition.[38] (Albert later reported that she was the only newcomer to the scientific party who did not succumb to seasickness en route.)[39]

One of Albert's major innovations, compared to the collection methods of his predecessors, was in the employment of baited traps in deep ocean water. He had begun using them onboard *Hirondelle*, but the weights involved, and the need to stay on or near station to retrieve them made it less than ideal. He had also experimented with using electric light as a lure, either in concert with the trap or on the surface of the water.

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[36] Albert, "Sur la deuxième campagne scientifique de la *Princesse Alice,*" *Comptes rendus de l'Académie des Sciences,* 30 décembre 1895. Reprinted in *Résultats des campagnes scientifiques*, f. 84, 15.

[37] For a history of marine illustration in the longer context of scientific illustration, see Samantha Muka, "Imagining the Ocean: Marine Artists and Our Visions of the Marine World," in *Soundings and Crossings: Doing Science at Sea 1800-1971*, ed. Katharine Anderson and Helen Rozwadowski, 245-276 (Sagamore Beach, MA: Science History Publications/Watson Publishing International, 2016).

[38] Albert, "Sur la troisième campagne scientifique de la *Princesse Alice*," *Comptes rendus de l'Académie des Sciences*, 14 décembre 1896. Reprinted in *Résultats des campagnes scientifiques* , f. 84, 18. See also Jacqueline Carpine-Lancre, *La campagne de la* Princesse-Alice *en 1896* (Monaco : Musée Océanographique, 1996), *passim*, but especially the photographs on p. 37 and 67, and examples of her work reproduced on p. 61 and 63. Between Mlle Le Roux and the botanist Hanna Maria Resvoll-Holmsen, who took part in a later Arctic expedition (see p. 145, below), the role of gender onboard Albert's yachts would appear a topic ripe for further investigation.

[39] Carpine-Lancre, *La campagne de la* Princesse-Alice *en 1896*, 36.

Princesse Alice's design included the necessary machinery to make better use of these devices.

Albert first conceived of traps as an improvement on the dredge or trawl, the rough passage and speed of movement of which would mangle delicate animals before they could even be retrieved. A trap could be baited and lowered to the bottom or to a set depth and left for twenty-four hours, marked by a buoy for easy station-keeping and eventual retrieval, while the ship performed other measurement or collection activities in the vicinity. Because of this need to remain nearby—Albert asserted that the trap must be left in place for twenty-four hours, and if weather prevented its retrieval, the ship might have to stay on station a week or more—they were difficult for expeditions whose schedules were not flexible—those "which do not enjoy absolute independence." This was why they had not been part of the research program of any of the larger, nationally-funded expeditions.[40]

Within his baited traps, Albert recognized that once caught, his smaller specimens were in danger of being eaten by anything larger in the trap (and occasionally something larger was eaten by a hoard of smaller specimens) during the extended period before they might be raised to the surface. To minimize the specimens thus lost, his traps included interior subsections which were smaller and enclosed by a finer mesh to collect and protect smaller fauna.[41] As with all of his equipment, Albert continually tinkered with net design, and he replaced the hemp line he had used to lower them, first with a metal wire, and when that proved too easily snapped—it "broke like glass" when subjected to torsion—with a

[40] Albert, "L'Outillage moderne," 203.

[41] Albert, "Deuxième campagne scientifique de l'*Hirondelle* dans l'Atlantique Nord," *Bull. Soc. de Géographie de Paris,* 6 May 1887; reprinted in *Résultats des campagnes scientifiques*, f. 84, 112.

multi-strand steel cable, which provided greater elasticity and superior tensile strength without adding significant diameter or weight.[42]

In 1895, the ship witnessed the dramatic chase and capture of a sperm whale by shore-based Azorean whalers. In its final throes, the whale vomited its last meal, and the quick-thinking prince had his crew collect what they could of the whale's erstwhile stomach contents with nets. Examining this gruesome haul, Albert found the remains of several cephalopods previously unknown to science. The whale, he realized, hunted at a depth which he had not yet been able to access for collecting purposes. He assisted the whalers in retrieving their prize and bargained with them for photographs and various body parts, but he also took away a new perception of the whale as a technology of collection.[43] Buchanan reported the incident to the British public in the *Times*, adding that as "soon as the yacht returned from the Azores the Prince set about equipping her for the whale fishery" and added an experienced whaler to the crew.[44] Albert's future encounters with whales always involved the detailed analysis of their stomach contents, and he reported to Buchanan that during the 1896 cruise they killed several whales and towed three of them back to Monaco, where they "were properly studied by Richard," their skeletons prepared,

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[42] Albert, "Deuxième campagne scientifique de l'*Hirondelle,*" 112 ; Albert, "Sur la deuxième campagne scientifique de la Princesse Alice," 13 ; Albert, "Les Progrès de l'Océanographie," 14 Jan 1904, 209. Quote from the latter.

[43] Albert, "Les Progrès de l'Océanographie," 14 Jan 1904, 214-215. For future encounters, see, for instance, Albert, "Sur la première campagne de l'Hirondelle IIe," *Comptes rendus de l'Académie des Sciences*, 13 May 1912; also printed in *Bull. Inst. Océan*., no. 234 (12 Jun 1912); reprinted in *Résultats des campagnes scientifiques*, f. 84, 55.

[44] J[ohn] Y[oung] Buchanan, "Monaco a whaling station," *The Times,* 15 Jun 1896.

and their blubber rendered into oil. "Monaco is now a whaling station," the Prince proudly announced.[45]

As great an improvement as the *Princesse Alice* was at its launch in 1891, it existed during a period of tremendous growth and development of oceanographic study, a process in which it played no small part. The turn of the twentieth century was also a period of acceleration in the growth of other relevant technologies, from electrification to refrigeration to radio. Inevitably, the outcome was a conviction on the part of the prince that this ship, too, was too small and that its equipment could only be upgraded so far. By 1896 he was actively planning its replacement, and he contracted with Laird Brothers of Birkenhead Iron Works, another British shipbuilder, in February 1897.[46] A steel-hulled, two-masted, schooner-rigged, auxiliary steamship, the new vessel was launched in November 1897, again under the name *Princesse Alice.* (Though not part of the yacht's registered name, the suffix *II* or *II*[e] was added in scientific reports for clarity's sake, a practice which historians generally follow.) Much larger than its predecessor, the new ship launched at 225 feet in length (16 feet were added to its length the following June to increase bunker capacity by 100 tons), 34 feet at the beam, and displaced 1270 (later 1400) tons.[47] It included all the steam-powered deck equipment oceanographic operations required and carried several small boats: by design a steam launch, dinghy, cutter, gig, and three whale boats, the various sizes and capabilities of which would allow off-ship

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[45] Albert, "Les Progrès de l'Océanographie," 14 Jan 1904, 214-215. For future encounters, see, for instance, Albert, "Sur la première campagne de l'*Hirondelle IIe*," 55; for the whales towed to Monaco, see Albert to J. Y. Buchanan, 7 June 1896, reproduced in Buchanan, "Monaco a whaling station."

[46] Articles of Agreement, 6 Feb 1897, folder C839, APM.

[47] "Launch of a Yacht for the Prince of Monaco," *Liverpool Daily Post*, 29 Nov 1892, folder C839, APM. The additional length is mentioned in Laird Brothers to HSH The Prince of Monaco, 11 Jun 1898, folder C839, APM.

operations under a variety of conditions. The ship was well-equipped in terms of distilling, electrical, and refrigeration equipment, which had now become standard. While probably the most advanced oceanographic vessel in existence at the time of its launch, the yacht was still very much a royal pleasure vessel, with well-appointed staterooms and bath for the family separated from those of the scientists and crew, and a seventeen-by-seventeen-foot dining room that could seat (and store plate and silver for) twelve people, plus an attached salon, to say nothing of the wine cellar. The galley included separate ranges for the crew and prince, and was adjoined by a scullery and bakery, and the large pantry included a steam-heated carving table.[48]

The chief laboratory was eighteen by nineteen feet, lit by circular portholes and a skylight, again with a refrigerating room for specimens below, with 750 cubic feet storage capacity. A smaller lab sat forward of the scientists' cabins, and a small dark room was equipped with running water.[49] Another laboratory was added in 1902, along with several other expansions.[50] These contained an "immense arsenal of instruments" which together provided facilities for physical and chemical analysis, and Albert reported proudly that the ship contained the first, and by 1905 still the only, physiological lab afloat.[51] An internal telephone system allowed communication throughout the ship.[52] To supply Albert's new

[48] Articles of Agreement, 6 Feb 1897, folder C839, APM; Laird Brothers to HSH The Prince of Monaco, 20 Dec 1898, folder C839, APM.

[49] Articles of Agreement, 6 Feb 1897, folder C839, APM.

[50] Laird Brothers to HSH The Prince of Monaco, 19 Dec 1902, folder C839, APM; Laird Brothers to Captain H. Carr, 4 Oct 1902, folder C839, APM.

[51] Albert, "L'Outillage moderne," 200.

[52] Laird Brothers to HSH The Prince of Monaco, 20 Dec 1898, folder C839, APM.

interest in whaling, it was equipped with all the necessary accoutrements, including harpoon cannons.[53]

On deck, the new ship was well-equipped to raise and lower the traps Albert preferred. He also worked to continually improve the use of nets and sampling devices. *Challenger* had been notable for the vast number of samples collected from the bottom, and the expedition had also employed surface nets, but Albert recognized several shortcomings of the apparatus used by it and other ships of its era. He had already addressed some of the problems with bottom-sampling, such as the mangling of specimens that occurred using a dredge or trawl. His traps also gathered bottom-swimming creatures which might be attracted by bait but which could evade a trawl. But the open mouth of the dredge or trawl posed another difficulty: how could one be sure that the specimens that did come up had come from the bottom and not been collected in passing on the way up or down? For creatures known to be bottom-dwellers—such as crustacea—the assumption was a safe one, but what of novel forms, or those whose varieties existed at all depths? Albert was of course not the first to recognize these shortcomings and attempt to address them, but he brought immense attention and resources to the problem. He acquired, tested, and modified equipment as he became aware of it and even designed and supervised the construction and modification of his own designs.

To reach the intermediate depths, he used a number of methods, some of which he adopted from fishermen. One such was longline fishing, in which he attached a series of large fishhooks to a 400 to 500 meter main line; the ends of the main line were attached to

[53] A.P., "Le Yacht du Prince de Monaco : Une visite à bord," *Nouvelliste de Rouen*, 1903, folder C839, APM.

buoys 500 to 600 meters apart with coiled auxiliary lines, which could be released simultaneously, allowing the main line to fall in a straight line to the chosen depth. Later this was modified to involve a weight at each end of the longline; one weight could be attached to a tow cable, allowing the ship to "fly" the line like a reversed kite. The longline was useful for gathering sharks and the cartilaginous fishes known as chimaera. The trammel net was similar, in that it employed a series of nets suspended between two buoys at the top and weighted along the bottom. Two large-meshed outer layers hung vertically around a fine-meshed central layer and worked as gill nets to entrap fish. Albert used a 200 meter long trammel, deployed to depths as low as 2600 meters.[54] Longlines and trammels, when anchored with buoys, were both subject to the same restrictions Albert had noted with his traps: a ship using them must have both the technological capability and the scheduling flexibility to remain on station long enough to retrieve them.

He also worked on methods of collecting water samples—and as time went on, bacteriological samples—which could be definitively associated with certain depths. Over the course of multiple expeditions, Albert and his associates perfected devices based on the design of the reversing thermometer, which allowed a weight dropped down the line or the quick jerk of a descending line to flip a sample tube upside down and open or close the device, trapping a water sample within. Richard, meanwhile, developed a similar device which could trap a seawater sample within a metal bottle full of mercury, thus preventing dissolved gases from escaping.[55] While he reported great strides in bacteriology, a "significant field" in which there was "still so much unknown," he

[54] Albert, "L'Outillage moderne," 203.
[55] Albert, "Les Progrès de l'Océanographie," 14 Jan 1904, 209.

"constantly contemplate[d] new means to be able to bring a greater light" to it. He also bemoaned the difficulty of getting others to work on its problems.[56]

At the same time, he developed bottom samplers that could take cores of increasing depth, based on an evolving design by Buchanan. By 1905 Albert reported taking bottom cores of up to 0.8 meters in length. [57] The use of these bottom samples grew increasingly sophisticated as well. After the *Princesse Alice II*'s eleventh expedition in 1909, he sent bottom samples to a Professor Gockel—presumably the physicist Albert Gockel—at the University of Fribourg for research on radioactivity.[58]

METEOROLOGY AT SEA

Albert also realized that a powerful deck engine designed to retrieve heavy weights from the depths could pull an object of similar resistance down from on high. He had been interested in studying meteorology at sea at least as early as 1887, when in August he and his crew endured a hurricane onboard the *Hirondelle*. While in the storm's dangerous semicircle, he spread oil upon the surface of the waters to calm the waves, following up the conclusions of a paper previously presented to the Académie des Sciences by the French

[56] Albert, "L'Outillage moderne," 206.

[57] Albert, "Sur la quatrième campagne de la *Princesse Alice IIe*," *Comptes rendus de l'Académie des Sciences*, 26 Jan 1903; reprinted in *Résultats des campagnes scientifiques*, f. 84, 30; Albert, "Sur la cinquième campagne de la *Princesse Alice IIe*," *Comptes rendus de l'Académie des Sciences*, 6 Jun 1904; reprinted in *Résultats des campagnes scientifiques*, f. 84, 32. Albert, "Sur la huitième campagne de *la Princesse Alice IIe*," *Comptes rendus de l'Académie des Sciences*, 14 Jan 1907; reprinted in *Résultats des campagnes scientifiques*, f. 84, 43; "L'Outillage moderne," 201.

[58] Albert, "Sur la onzième campagne de la *Princesse Alice IIe*," *Comptes rendus de l'Académie des Sciences*, 30 May 1910; also printed in *Bull. Inst. Océan*., no. 186 (29 Nov 1910); reprinted in *Résultats des campagnes scientifiques*, f. 84, 47-8.

Admiral George Charles Cloué with apparent success.[59] Upon his safe return to port, Albert wrote the meteorological bureau in London requesting the logs of any other ships that had experienced the same storm, hoping to assemble a meteorological picture for the day.[60]

Meteorology—which Albert included within the "domain of oceanography"—also fit into Albert's view of science as a series of steps to be approached sequentially.[61] By 1904, onboard the much more powerful *Princesse Alice II*, he felt ready to tackle the atmosphere more actively, after a few alterations to his shipboard sounding gear. He began that year's campaign with preliminary work off Monaco in March and April, experimenting with meteorological kites under the direction of Professor Hugo Hergesell of the University of Strasbourg, at the latter's suggestion.[62] The scientific campaign proper ran from July through September.[63] To study the trade winds in the Atlantic, Albert and Hergesell sent their kites up twelve times to altitudes as high as 4500 meters, and they made an additional ten ascents in the Mediterranean. Albert was later able to recruit both the German Kaiser Wilhelm II and the Portuguese government to make similar observations in the areas under their control or which they visited. Hergesell's

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[59] Albert, "Sur la troisième campagne scientifique de l'*Hirondelle*," Comptes rendus des séances de l'Acadèmie des Sciences, 24 Oct 1887. Reprinted in *Résultats des campagnes scientifiques*, f. 84, 8. Cloué summarized US reports for the Académie in 1887, so these would recently have appeared when Albert tried them, Charles Tanford, *Ben Franklin Stilled the Waves: An Informal History of Pouring Oil on Water with Reflections on the Ups and Downs of Scientific Life in General* (Oxford: Oxford University Press, 2004), 120.

[60] Albert, "Sur des courbes barométriques enregistrées pendant la troisième campagne scientifique de l'*Hirondelle*," *Comptes rendus l'Académie des Sciences*, 16 Jan 1888; reprinted in *Résultats des campagnes scientifiques*, f. 84, 144.

[61] Albert, "Studies of the Ocean," *The Scientific Monthly* 13, no. 2 (Aug 1921), 182.

[62] Albert, "Sur la sixième campagne de la *Princesse Alice II*," *Comptes rendus de l'Académie des Sciences,* 22 May 1905; reprinted in *Résultats des campagnes scientifiques*, f. 84, 35. Carpine, *La pratique de l'océanographie*, 226. Albert, "Meteorological researches in the high atmosphere," address delivered before the Society in Edinburgh on 17 Jan 1907, *The Scottish Geographical Magazine*, Mar 1907: 113-122; reprinted in *Résultats des campagnes scientifiques*, f. 84, 158.

[63] Albert, "Sur la sixième campagne de la *Princesse Alice II*," 35.

experiments looked down as well as up, studying pressure with a specially constructed manometer to depths of 4282 meters.[64] Hergesell reported the results in his own paper to the Académie, as he did again the following year, when in addition to thirteen more kite ascensions, he and Albert launched and recovered a series of twenty-six balloons, to altitudes up to 16,000 meters.[65]

By 1906 Albert, through his usual method of iterative improvement, had developed a sophisticated technological suite for meteorological studies.[66] During that summer's campaign in Arctic waters he was able to report studying the upper atmosphere with four kite ascensions up to 800 meters, three tethered balloons up to 2700 meters, five weather balloons up to 7500 meters, and eighteen pilot balloons up to 29,800 meters.[67]

Kites had been used to study the atmosphere in the US as early as 1890, and by 1894 American meteorologists had followed oceanographers in the adoption of steel sounding wire to replace the kites' line. They were, indeed, "sounding" the atmosphere. The kites themselves were on the Hagrave model, originally Australian, which had been adopted by the Americans, and they were made of wood, metal wire, and nainsook cotton—a fine, lightweight, silk-like muslin. They carried "meteographs" constructed of aluminum by a Paris firm to measure altitude.[68] With time, this arrangement grew more sophisticated, so that Albert was sending up a package of instruments, including a

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[64] Albert, "Sur la sixième campagne de la *Princesse Alice II*," 37.

[65] Albert, "Sur la sixième campagne de la *Princesse Alice II*," 37. Hergesell, note, *Comptes rendus*, 9 Apr 1906, 919-21 ; "Sur les vents locaux du voisinage des iles Canaries," 11 Jun 1906, 1360-63. Albert, "Sur la septième campagne de la *Princesse Alice IIe,*" *Comptes rendus de l'Académie des Sciences*, 12 Mar 1906, reprinted in *Résultats des campagnes scientifiques*, f. 84, 41.

[66] Albert, "Sur la huitième campagne de la *Princesse Alice II^e^*," 41-43.

[67] Albert, "Sur la huitième campagne de la *Princesse Alice II^e^*," 41-43.

[68] Albert, "Meteorological researches in the high atmosphere," 158. Carpine, *La pratique de l'océanographie*, 225.

barometer, thermometer, and hygrometer, using a string of kites, each of which added additional lift to the line. The kite must be hoisted up to the mizzenmast head to get it above the ship's own influence on the surface winds, with the line handled by several men in stout gloves, then the masthead block was brought down to the deck where the kite line could be joined to the steel wire wound on the steam winch. This complicated setup required the *Princesse Alice II*'s capabilities not just to handle the kite wire, but also to maintain speed; like a child running across a lawn, the ship had to maintain enough headway to create a relative wind of seven meters per second to keep the kite in the air. Speed must be maintained through the operation, and as with sounding the sea, sounding the heights could take most of a day, during which the ship might cover fifty to sixty miles. This technique, then, needed the sea room of the open ocean. Theoretically, Albert claimed, if both kite and sounding wire diameter were progressively increased, the only limit to attainable height would be atmospheric rarefication. However, he found that the difficulty of handling kites onboard ship and the irregularity of air currents at various altitudes imposed a practical limit of about 7000 meters, and to approach this height required the outlay of almost three times as many meters of wire.[69] And the operation remained entirely dependent on the wind to give the kite lift. During the 1906 campaign, kite ascensions were rarely possible because of the Arctic region's frequent calms.[70]

Balloons provided an alternative. Scientists had long recognized the potential for balloons to make visible the winds at altitude, and small balloons had been used to carry thermometers for atmospheric sounding as early as 1892. "International ascensions"

[69] Albert, "Meteorological researches in the high atmosphere," 159-161.
[70] Albert, "Sur la huitième campagne de la *Princesse Alice II*e," 42-43.

during which such balloons were released from several European countries simultaneously took place in 1896 and 1898; Albert took part in a launch from Paris during the latter.[71] Albert eventually used scientific balloons in three ways: tethered balloons, launched from the ship in a series not unlike that described for his kites; weather balloons [ballons-sonde], which were released carrying instruments and chased for eventual recovery; and pilot balloons, which were disposable balloons released without instruments so that the wind could be observed through their movements.

Tethered balloons, like kites, were attached to the ship and launched one at a time, though they did not require the ship to be moving at speed. This made them useful when it was overcast, or when the ship was near enough land to be unable to either chase a weather balloon or maintain headway for a kite. The balloons were launched one at a time, and when each stopped rising, another balloon could be allowed to slide up the wire, adding additional lift. When the desired height was reached, a last balloon was added carrying the recording instruments.[72]

Weather balloons, on the other hand, were released from the ship to the mercy of the winds. Still working with Hergesell, Albert conducted early trials in spring 1905. Hergesell again adapted American methods, with the added innovation of launching the balloons in tandem to "set" a predetermined maximum height.[73] As Albert explained the method,

> Two very light india-rubber balloons were inflated, one to slightly greater extent than the other, with hydrogen of which a supply was carried in steel cylinders. The less inflated balloon carried the registering instrument, enclosed in a small

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[71] Carpine, *La pratique de l'océanographie*, 225.
[72] Albert, "Meteorological researches in the high atmosphere," 163.
[73] Carpine, *La pratique de l'océanographie*, 225.

> basket . . . as well as a float suspended at the end of a line 50 meters long. The more inflated balloon was connected with the other by a line also 50 meters in length. Its function was, first, to facilitate the ascent by rendering the necessary assistance to the other balloon and, afterwards, to facilitate its descent with the registering instrument by quitting it at the altitude determined before-hand by the degree of inflation given, on which depends the height at which the balloon burst. The first balloon, now become a simple parachute, brought the instrument back towards the sea, above which it remained floating so soon as the float at the end of the stray line touched the surface of the water. In this way, the basket containing the instrument was kept clear of the waves, and the balloon remained visible at a distance of 8 to 10 miles.[74]

A later innovation allowed the lifting balloon to be detached by the electric current from a small onboard battery, touched off when the recording instrument made contact with a pre-set conductor corresponding with the desired altitude. The battery was enclosed in a "calorific envelope" to protect it from cold at altitude. This setup allowed maximum desired height to be set far more accurately.[75] The instruments sent aloft were meant to be self-registering for recovery and later analysis. A pen would trace a curve on a cylinder coated with lamp-black deposited by a sooty petroleum lamp flame. The resultant layer of grease rendered the record readable even if it were immersed in seawater before it could be recovered. Albert reported one incident in which an instrument was lost off Corsica and found ashore in Provence fifteen days later, its cylinder still readable. [76]

While the balloon was up, it was tracked with a sextant, and the ship must follow at full speed to keep it in sight. Operations were thus possible only in very clear weather or the instrument payload would be lost (though over time they developed a formula with which the balloon’s eventual touchdown location could be predicted). On the 1906 Arctic

[74] Albert, "Meteorological researches in the high atmosphere," 162.
[75] Albert, "Meteorological researches in the high atmosphere," 163.
[76] Albert, "Meteorological researches in the high atmosphere," 160-1.

expedition, the use of these balloons was rendered impossible by "the almost permanent fog in the vicinity."[77]

Along the coast, however, Albert found clear weather, particularly suited to the use of pilot balloons. These balloons were inflated to something less than a meter in diameter— "small enough to be embraced by the arms of a man"—and released without payload, often from shore. Their flight could be tracked by theodolite to determine the direction and speed of the winds at each altitude as they rose, until they finally disappeared from sight through some combination of altitude and distance. Thanks to the clear Arctic air on the 1906 expedition, Albert reported, they were able to track a balloon of seventy centimeters diameter to a distance of eighty kilometers, and it only disappeared when it finally burst.[78]

SCIENCE AS AN INTERNATIONAL ENDEAVOUR

Albert saw meteorology as a field brimming with possibilities but best approached through international effort. After his 1905 and 1906 cruises, he asserted that "if the principal states of the world were willing to diminish a little the expense of international quarrels by submitting them to the judgment of a tribunal less costly than that of war, and if they preserved more of their resources for the veritable interests of humanity, it would be possible with powerful means, very soon to ascertain the laws of meteorology."[79] He was

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[77] Albert, "Meteorological researches in the high atmosphere," 162 ; Albert, "Sur la huitième campagne de la *Princesse Alice II*ᵉ," 42-43.

[78] Quotation from Albert, "Meteorological researches in the high atmosphere," 165. Albert reported being able to distinguish each of four men with their equipment on the side of a glacier a distance of forty kilometers thanks to this same clarity of air, "Sur la huitième campagne de la *Princesse Alice II*ᵉ," 42-43.

[79] Albert, "Meteorological researches in the high atmosphere," 165.

hardly beating a new drum. Albert had from an early period asserted the suitability of the oceans as a field uniquely suited to international effort. He pushed this agenda throughout his scientific career, which was in many ways, thanks to his status as a head of state, inseparable from his political career.

France was, of course, his first field of effort beyond his tiny principality, which is surprising neither for geographical reasons—since it surrounded Monaco after the latter's loss of its eastern most territory in 1861—nor for personal ones: Albert was, after all, actually born in Paris, served in the French navy during the war with Prussia, spent significant amounts of his time in Paris, and considered the country his second home. He served as patron to numerous French scientists and reported his results to the Académie in Paris; he was elected a "foreign associate" member in 1909.[80] Early in his scientific endeavors he hoped to build a zoological station at Monaco, along the lines of the Stazione Zoologica in Naples, which from 1872 has served as a research destination for marine scientists from around Europe and beyond. Albert envisioned a grand aquarium open to the public and populated with specimens acquired locally and during his cruises. Qualified scientists of any nationality could work with these specimens in well-equipped biological, chemistry, and physiological laboratories and a library directly above the aquarium.[81] Eventually, this became the Musée océanographique, of which the cornerstone was laid in 1899, and which still exists today, with Albert's long-time collaborator Jules Richard as its first director. He endowed the Institut océanographique

[80] Carpine-Lancre, "Chronologie sommaire," 131.
[81] Albert, "Station Zoologique de Monaco," *Amis de Musée Oceánographique de Monaco*, no. 13 (Jan 1953) : 4-5.

in Paris, opened in 1906, as the museé's academic counterpoint.[82] The Musée followed Albert's original vision to the extent that it and its environs became a showcase for the instruments developed and specimens gathered during his campaigns. Albert encouraged scientists to work there, and even to join the musée's staff, regardless of nationality, as in the cases of East Prussian-born Alexander Nathansohn, who studied there in 1908 to 1909 and again thirty years later, and Mieczyslaw Oxner, who in 1907 became an assistant director at the musée.[83]

At sea, Albert's scientific staffs were always international, as the occasional presence of the Scotsman Buchanan attests. His series of trips to Spitzberg (Spitsbergen/Svalbard) in the Arctic Ocean, for instance, were couched explicitly as an international effort. Several of the participants in the first voyage, in 1898, had been aboard before, including Jules Richard, John Y. Buchanan, and Henri Neuville, of the Muséum de Paris. They were joined by Buchanan's countryman William Speirs Bruce, who had previous Arctic and Antarctic experience; Karl Brandt, a professor of zoology at the University of Kiel; and Count Witold Lovatelli Colombo, who served as expedition artist. As this trip was also the first in the *Princesse Alice II*, Albert arranged to meet the

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[82] At the same time, Albert complained that France, "alas! appear[ed] indifferent to the progress of oceanography," "Les Progrès de l'Océanographie," 14 Jan 1904, 212. The institute was in part an effort to provide the educational foundation to counter this failure, noticed not just by Albert but by historians since. Eric Mills calls France's failure to develop a noticeably presence in oceanography during an era when it was growing and gelling as a field, despite Albert's leadership in that process, a paradox, Mills, "'Découverte de l'océan': Monaco and the Failure of French Oceanography," chapter 6 in *The Fluid Envelope of the Planet: How the Study of Ocean Currents Became a Science* (Toronto: University of Toronto Press, 2009), 162-191. Antony Adler, on the other hand, points to the development of marine zoological laboratories on the French coast as an alternative path for France, embracing what would become marine biology rather than the new, dynamical physical methods of oceanography, Adler, "The Ocean Laboratory: Exploration, Fieldwork, and Science at Sea," Ph.D. Dissertation (University of Washington, 2014), 73.

[83] Mills, *Biological Oceanography: An Early History, 1870-1960* (Toronto: University of Toronto Press, 2012), 109-110. On page 116 Mills gives the dates for Nathansohn's work as 1907-8, but the chronology suggests the slightly later dates are correct.

German emperor with three of the latter's warships en route to the Arctic Circle: "It was there, in a depth of 1095 meters that [the yacht] . . . under the eyes of the emperor and with the aid of a scientific staff in which five nationalities were represented, made its debut in the service of science."[84] The group performed glacier studies at the behest of French glaciologist Charles Rabot; Bruce and Buchanan gathered plankton with a net designed (and sent aboard the yacht personally) by German zoologist Victor Hensen; and Albert sent his samples for analysis to Swedish geologist Alfred Nathorst.[85] His 1907 visit to the same area included collaborative work with the Norwegian army and Norwegian botanist Hanna Maria Resvoll-Holmsen, who collected specimens for the musée in Monaco and later published results with its press.[86]

As has been mentioned above, Albert also participated in, encouraged, and organized broader international efforts at oceanography and meteorology. These were both because he recognized the need for simultaneous or near simultaneous observation across vast geographical areas, and because he recognized his principality could not afford to do worldwide science. Even as he designed bigger and better vessels and more suitable equipment, he realized early on that there were limits to the work that could be accomplished with a single vessel. By 1895 he was already thinking of more extensive

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[84] Albert, "Première campagne de la *Princesse Alice II*e", 23-24; quotation is from Albert, "Exploration océanographique aux régions polaires," *Bulletin du Muséum d'histoire naturelle,* 1899, no. 1: 6-17; reprinted in *Résultats des campagnes scientifiques*, f. 84, 62.

[85] Albert, "Première campagne de la *Princesse Alice II*e", 23-24; Albert, "Exploration océanographique aux régions polaires," *Bulletin du Muséum d'histoire naturelle,* 1899, no. 1: 6-17 ; reprinted in *Résultats des campagnes scientifiques*, f. 84, 67.

[86] Albert refers to the "botaniste" as Mme Dieset, though she had divorced Hans Dieset in 1901, "Sur la neuvième campagne de la *Princesse Alice II,*" *Comptes rendus de l'Académie des Sciences,* 15 Jun 1908; reprinted in *Résultats des campagnes scientifiques accomplies sur son yacht*, f. 84 (1932): 44-45.

projects which would require several ships working together, and he made arguments for such projects almost every time he addressed a public audience, especially abroad.[87]

Recognizing the precedent of the *Challenger* alongside his own role as a patron, he tried to recruit governments, and particularly their navies, to the cause of science. He had some success, as when Germany sent the ship *Planet* to the Atlantic and Indian oceans "to continue and extend [Albert's] aerial explorations", while American meteorologist Abbott Lawrence Rotch—who had originated the use of meteorological kites—and French meteorologist Léon Teisserenc de Bort "fitted out and used during 1905 and 1906 a ship of their own for this purpose."[88] When Albert reported these foreign efforts to the Royal Scottish Geographical Society he no doubt hoped to stir the British to similar action.

Albert also used his social standing to attempt to recruit his peers among Europe's ruling families to the cause of science. He reported the interest of Alphonse VIII, king of Spain, in his operational methods during his 1903 campaign; "eager to see Spain join the movement that leads almost all the maritime nations towards oceanography," Alphonse observed the *Princesse Alice*'s operation in the Bay of Biscay.[89] We have seen his efforts to recruit Wilhelm II in Germany. He also appears to have brought Carlos I,

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[87] Albert, "Sur la deuxième campagne scientifique de la *Princesse Alice,*" 18. He later expressed similar sentiments in Albert, "Les Progrès de l'Océanographie," 14 Jan 1904, 208-9. In this he echoed Matthew Fontaine Maury's earlier calls in public for a for international and collaborative scientific projects, but he does not seem to have been conscious of doing so, or at least he never referred to Maury. Within a few years, ocean scientists interested in fisheries questions were beginning to organize an international effort to address them that would lead them to organize the International Council for the Exploration of the Sea (ICES)—founded in 1902—to address them via collaborative effort at sea and in a central laboratory. See Helen Rozwadwoski, *The Sea Knows No Boundaries: A Century of Marine Science under ICES* (Seattle: International Council for the Exploration of the Sea/University of Washington Press, 2002), especially chapter 1, "Forging International Science of the Sea," 9-41.

[88] Albert, "Meteorological researches in the high atmosphere," 165.

[89] Albert, "Sur la cinquième campagne de la *Princesse Alice IIe*," 34.

king of Portugal, into the field, either during visits to *Princesse Alice* when the ship stopped in Lisbon in 1894 and 1895, or with the 1896 discovery of the Princesse Alice Bank in Portuguese waters. Though Carlos did begin his own researches, they were quite limited in both scale and scope, and in a way, somewhat contrary to Albert's international goals, as part of Carlos's motivation was a belief that exploration of Portuguese waters should be conducted by Portuguese ships.[90]

Though Albert achieved limited cooperation from these and other governments in the loaning of individual officers or the occasional involvement of warships, it remained a hard sell. He expressed his frustration characteristically when he spoke in Paris in 1905 at the opening of the oceanographic course at the Institut: "To much increase the power of the equipment which I use now would require several ships working together, and, therefore, to find in some navy an ally. However, it is still not easy to persuade the states of Europe that the interests of everyone lies rather in the solution of the problems of Nature, where one finds the key to things precious to all of humanity, than in crazy armaments and senseless wars."[91]

Albert played a key role in organizing international conferences and enjoyed some success in this direction. He chaired conferences on oceanography in Monaco and Paris which went some way towards assisting the slowly coalescing field into at least its adolescence, including the first Congrès de l'Association international de la marine in

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[90] Carpine-Lancre, "Oceanographic sovereigns: Prince Albert I of Monaco and King Carlos of Portugal," in *Understanding the Oceans: A Century of Ocean Exploration*, ed. M. Deacon, T. Rice, and C. Summerhayes, 56-68 (London; New York: UCL Press, 2001), 63. See also Carpine-Lancre and Luiz Vieira Caldas Saldanha, *Dom Carlos I, Roi de Portugal ; Albert I^er^, Prince de Monaco: Souverains océanographes* (Lisbon : Fondation Calouste Gulbenkian, 1992).

[91] Albert, "L'outillage moderne," 206.

1901.[92] He also presided over the April 1903 meeting which launched an international effort to assemble a new chart series, the General Bathymetric Chart of the Ocean—itself an important technology of oceanography and a project that persists to this day.[93] He spoke before numerous other scientific bodies in Europe and the United States.[94]

STORM UPON THE WATERS

By 1910, Albert's studies had again outgrown even the well-equipped *Princesse Alice II*, and he again looked to a newer and larger platform. The new yacht, this time built closer to home by les Forges et chantiers de la Méditerranée, in La Seyne, near Toulon, was named *Hirondelle* (though it again often took the unofficial II or IIe for clarity's sake.) Displacing 1600 tons and equipped with two engines totaling 1200 hp, the new yacht was equipped with even larger laboratories than its predecessors.[95]

Over the next few years, Albert continued his established pattern of summer expeditions, largely working in his usual stomping grounds in the Mediterranean and the Atlantic between the Azores and Canaries. He and his team continued to improve a series of ballasted nets which could be towed at intermediate depths. They also took

[92] Carpine-Lancre, "Chronologie sommaire," 127. This took place in the midst of a series of organizational meetings which would culminate in the 1902 founding of the International Council for the Exploration of the Sea (ICES), a mostly European body intended for the development of fisheries science. ICES's continued existence makes it a striking exception to Albert's complaints of limited interest in international efforts, although the organizers' struggles to get sustained interest from the eventual member countries do support his assertion. See Helen M. Rozwadowski, *The Sea Knows No Boundaries: A Century of Marine Science under ICES* (Seattle: International Council for the Exploration of the Sea/University of Washington Press, 2002.

[93] Carpine-Lancre, *The history of GEBCO 1903-2003: the 100-year story of the General Bathymetric Chart of the Oceans* (Lemmer, The Netherlands: GITC bv, 2003), 2; "General Bathymetric Chart of the Oceans." Accessed 21 Mar 2017. Online at http://www.gebco.net/

[94] Albert, "Discours sur l'Océan," speech to the National Academy of Sciences, Washington, DC, 25 Apr 1921, in *Résultats des campagnes scientifiques*, f. 84, 344-357.

[95] Albert, "Sur la première campagne de l'*Hirondelle II*e," 52. Albert and his second wife had separated in 1902, perhaps prompting his return to the earlier name for his next yacht.

several whales and analyzed their stomach contents.[96] Albert's team did extensive work on plankton, and continued to perfect means for plankton sampling. Among his successes, Albert pointed to continuing confirmation of a daily vertical migration by numerous marine organisms, a theory he had held for years and which he was pleased to see confirmed by Scottish oceanographer John Murray (another *Challenger* alumnus) and Norwegian marine biologist Johan Hjort during their recent work on the Norwegian vessel *Michael Sars*.[97]

Albert still reported new species found with each new improvement to the nets, but the work done in the ships' onboard laboratories had become more sophisticated over the years. Experiments performed at the prince's instigation onboard *Princesse Alice II* in 1901 by Charles Richet, of the Faculté de Médecine de Paris, had led to the discovery of anaphylaxis; in 1913 this important physiological work was recognized internationally when Richet was awarded the Nobel Prize in Physiology or Medicine.[98] Meanwhile, physiologist Albert Ranc joined the scientific staff during these years and studied the relationship between glucose and thermometric level and glycogen function in animals with large reserves of liver fat.[99]

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[96] Albert, "Sur la première campagne de l'*Hirondelle II*e," 52.

[97] Albert, "Sur la première campagne de l'*Hirondelle II*e," 56. Murray and Hjort had just published their results in *The Depths of the Ocean: A General Account of the Modern Science of Oceanography Based Largely on the Scientific Researches of the Norwegian Steamer* Michael Sars *in the North Atlantic* (London: Macmillan, 1912). In addition to the network of researchers he supported and corresponded with personally, Albert clearly kept abreast of other work in the field.

[98] Albert, "Sur la troisième campagne de la *Princesse Alice II*e," *Comptes rendus de l'Académie des Sciences,* 28 Apr 1902; reprinted in *Résultats des campagnes scientifiques*, f. 84, 27. Richet, "Anaphylaxis," Nobel lecture, 11 Dec 1913, Nobelprize.org: The Official Website of the Nobel Prize, Nobel Media AB 2014. Accessed 20 March 2017. Online at http://www.nobelprize.org/nobel_prizes/medicine/laureates/1913/richet-lecture.html

[99] Albert, "Vingt-cinquiéme campagne scientifique (*Hirondelle II)*," *Comptes rendus de l'Académie des Sciences,* 9 Jun 1913; also printed in *Bull. Inst. Océan.*, no. 268 (1 Jul 1913); reprinted in *Résultats des campagnes scientifiques*, f. 84, 57.

On 16 July 1914, Albert and his staff onboard *Hirondelle II* left Le Havre for the Azores, with a full schedule of scientific sampling and experimentation planned for the summer. It was to be the twenty-seventh expedition of his scientific career. Arriving in Ponta Delgada at the end of the month, they received news of Europe's descent towards war, which they watched via a flurry of telegrams over the next few days. They left 1 August, making almost directly for home, where Albert's largely French crew and non-scientific staff left to mobilize.[100] Though he managed a small cruise in local waters the following summer, the next few years of war put a halt to Albert's work at sea. By war's end, Albert was seventy years old, and while he still spoke passionately about ocean science and provided leadership in the field—recognized by the National Academy of Sciences in the US with the awarding of the Agassiz medal in 1918—Albert's days of hands-on oceanography aboard his yachts were done.[101] Given Albert's consistent efforts towards internationalism and peace, it is perhaps ironic that Albert's career at sea should have been ended largely by the coming of a world war.

CONCLUSION: ALBERT AND SCIENCE AT SEA

After a period of illness, Albert died 26 June 1922, at the age of 73. He was succeeded on the throne of Monaco by Louis II, the son of Albert's ill-fated first marriage. Louis had gone with his mother when she left Monaco; he did not return until the age of eleven, by which time he and his father had probably missed the opportunity to develop a

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[100] Jules Richard, "Vingt-septième campagne scientifique (Hirondelle II)," in *Résultats des campagnes scientifiques*, f. 84, 61. Drafts and receipts logs for at least some of the telegrams are in folder C854, APM.

[101] "Alexander Agassiz Medal," National Academy of Sciences website, accessed 7 December 2016, online at http://www.nasonline.org/programs/awards/alexander-agassiz-medal.html

close relationship. Albert spent his time ashore involved with the demands of public life and as much time as he could at sea; Louis left for school and thence a French military career as soon as he was able. While the family tragedy no doubt complicated the politics of succession, it also boded ill for Albert's scientific legacy, as Louis never developed the interest in the ocean sciences which his father had had. *Hirondelle II* was eventually sold, as Louis pursued his own interests. Albert left money to complete the publication of the series of *Résultats des campagnes scientifiques accompli sur son yacht* after his death, but the economic situation in the 1920s required Jules Richard, in whose care the project was left, to compromise on the paper used for the later editions.

Much has been made, and with reason, of Prince Albert's efforts towards peace over the course of his lifetime. Albert devoted much of his life to the promotion of peace, a goal worthwhile in itself, but he closely tied it to the promotion of science. In an era when much of Europe and the world were launching a period of competitive naval build-up of increasingly heavy ships with increasingly heavy guns, Albert argued that "[T]he keeping of millions of men, the manufacture of hundred ton guns, and the launching of ironclads and torpedo vessels, do not leave much room in the budgets of most nations for intellectual work, or for the labour of men who would willingly devote themselves to the best interests of their fellowmen."[102] Militarism, in other words, was a waste of money and resources which left little to pursue more peaceful and lofty goals. Albert also argued the other side of the same coin: Science, actively pursued, would bring peace and prosperity, not simply because it replaced militarism, but because knowledge of the natural

[102] Albert, "New Ship," 193-4.

world would lead inherently to improvements in life and prosperity.[103] Science alone, as historian Eric Mills has pointed out, was not "Albert 1er's beacon of international collaboration and social stability," because he actively advocated for other, more political projects of de-escalation and even social justice.[104] But Albert saw possibilities for abundant food, full employment, and other keys to a peaceful and prosperous society in an understanding of the atmosphere and oceans, and the creatures who lived there.[105]

Setting aside his position on the political world stage, though, Albert's quotidian scientific efforts also deserve some examination. Albert was not a practicing scientist himself, or not in the sense which the term had acquired by the end of the nineteenth century, with its implications of formal scientific education, work for pay, and hands on experimentation. He was clearly important to the coalescing field of oceanography as a patron of individual scientists and as a promoter of their work; his reports to the Académie not only summarized the most recent expedition, but also named the individual scientists who had participated, credited their work, and in many cases pointed readers to the scientists' own forthcoming publications for further details. He took suggestions from leaders in the field, from Pouchet and his work on currents at the beginning of his scientific career to Hergesell's meteorology towards the end, but it was always Albert himself who personally set the itinerary and chose the focus of each expedition. He seems to have

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[103] See, for instance, Albert, "Les Progrès de l'Océanographie," speech in Spanish before the Société royale de Géographie de Madrid, Jan 1912; printed in French translation in *Résultats des campagnes scientifiques*, f. 84, 325.

[104] Mills, "Editorial – Rediscovering the Prince of Monaco," *History of Oceanography Newsletter* 11 (Sept 1999): 1.

[105] These sentiments would be echoed a half century later by those who sought to ease Cold War tensions through international scientific efforts and believed the ocean sciences particularly suited to the purpose. See Jacob Darwin Hamblin, "Visions of International Scientific Cooperation: The Case of Oceanic Science 1920-1955," *Minerva* 38 (2000): 393-423, and his *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005).

recognized his own strengths, though, and having set the agenda, then turned his scientists loose in the laboratory and both supported their needs and credited their results. "Nowadays the scientific men who forsake their laboratories for the open air are many, but the organization of a scientific oceanic expedition is not easy," he noted; both a captain who understands the work to be done and scientists who understand the exigencies of working at sea are required to make an expedition successful. He believed he was the former, and by also being their patron, he was able to hand select the latter.[106] This role as a rather hands-on patron made him a sort of early director of projects, not unlike those who would later administrate funds from organizations such as the Office of Naval Research or the National Science Foundation in the US. This administrative work was important to the further development of oceanography and of its related fields—witness Richet's Nobel Prize—but it becomes especially obvious when it comes to Albert's use, development, and promotion of technology.

Albert himself pointed to the technologies of oceanography as the object of his most particular attention during his campaigns. Because of the unique environment of this "new science," it required a particular kind of expertise to develop the best tools for the job: "the experience of a sailor and the exact understanding of the questions which are to be studied." Albert may not have received a formal scientific education, but he had received one as a mariner, had spent years at sea even before becoming interested in conducting science there, and was an intelligent and well-read scientific enthusiast. This fairly unique combination suggested that the way his skill set could best be used to

[106] Albert, "New Ship," 193-4.

advance the cause was through the development of oceanographic equipment.[107] That his skill set came attached to a princely budget did not hurt.

To Albert it was obvious that ocean scientists must conduct work at sea (unlike those who worked someplace like the Stazione Zoologica in Naples, where specimens, alienated from their environments, were brought to the work table for each scientist).[108] Albert believed that the minds of those who made their observations in the field "gradually acquired a certain sagacity due to the contemplation of nature in the open, which it is difficult to acquire within the four walls of a laboratory, and without which great discoveries often remain barren."[109] He thus equipped his ships with increasingly well-provisioned laboratories, though he still sent specimens to respected scholars around Europe. This balance of ship and shore work was necessary and even preferred, because shipboard labs, however well-equipped, remained subject to the difficulties of their environment. "I do not think that one ought to carry too far an analysis or other delicate observations during the voyage," Albert argued.

> The movement and the noise, however subdued they may be, are a cause of constant disturbance; on the other hand, one would have to have exceptional power over one's mind, to be able to arrest it in the exciting moments of a general investigation, whilst other experiments, of an engrossing character, were being carried on without interruption, on the largest scale and with the full power of the ship.
>
> To follow out under these conditions any profound idea does not seem to me to be an easy matter, and I think that it ought to be one's chief object, during the work at sea, to make the best arrangements for collecting a great number of facts at the most favourable moments, and for noting all the details which strike

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107 Albert, "L'Outillage moderne," 200.

108 Adler has demonstrated that a belief in gathering one's own specimens was also a key part of the formation of shore-side marine laboratories in France during the nineteenth and into the twentieth century. See his "The Hybrid Shore: The Marine Station Movement and Scientific Uses of the Littoral (1843-1910)," chapter 2 in *The Ocean Laboratory*, 68-124.

109 Albert, "New Ship," 193.

> the eye and the mind. It is thus that a painter makes a study from nature, which afterwards becomes a masterpiece, when the impressions he has received have matured in the silence of the studio.[110]

That said, he argued, the "precarious circumstances" under which scientific work was conducted at sea could be remedied with sufficiently precise instruments.[111] In this he echoed the arguments underlying so many of the *Challenger* publications, with their precise descriptions of equipment developed at sea and thus rendering that environment an acceptable laboratory. Albert, who consciously positioned himself as taking up the mantle of oceanography once borne by the *Challenger* scientists, did so with a similarly conscious placement of his yachts as the ship's own successors: continually evolving technological systems with which to render the ocean-atmosphere knowable, and eventually known.

[110] Albert, "New Ship," 197-8.
[111] Albert, "L'Outillage moderne," 200.

CHAPTER 4: The Deutsche Atlantische Expedition, 1925-1927

". . . it is possible not only to give a powerful impetus to our own research activity, but at the same time to give thought to the views of our rivals and offer the world a new, permanent impression of the irrepressible German potential and scientific proficiency. . . . Our rivals may very well drive the German flag from the ocean by forcing us to give up our naval and merchant fleet, but they cannot stop us from rehabilitating it again and earning recognition for it through a great cultural act. An oceanographic expedition is thus equally in the interests of Germany and German science."

"[T]his expedition was the living assurance of the unbroken will of our nation to survive."

-- Fritz Spiess[1]

As Albert's case shows, the opportunities for scientists—and especially Europeans—to do science at sea was greatly curtailed during the Great War.[2] This limitation was caused both by the problem of safety in an environment of unrestricted submarine warfare and by the massive redirection of resources—both materiel and personnel—required by the war efforts of the participating countries. In Germany, for instance, following a model which would become standard for many nations later in the century, the navy enlisted the help of top oceanographers, such as Alfred Merz, who applied their expertise to the war effort through study of the conditions German submarines were likely to encounter in specific locations.[3]

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1 Spiess, *The Meteor Expedition: Scientific Results of the German Atlantic Expedition, 1925-1927*, trans. ed. William J. Emery (New Delhi: Amerind Publishing Co., 1985), 10-11, 395.

2 In retrospect, the Great War proved to be of particular significance to fisheries science, as mining and submarine operations in the North Sea essentially imposed a four-year hiatus on fishing. After the war, fish stocks had rebounded significantly. This was referred to later as the "Great Fishing Experiment" (or eventually the "First Great Fishing Experiment," as a similar effect noted during World War II became the second).

3 For the relationship between the US navy and oceanographers, see Gary E. Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment* (College Station: Texas A & M University Press, 2001). See also Chandra Mukerji, *A Fragile Power: Scientists and the State* (Princeton : Princeton University Press, 1989).

Before the war, Merz had been a rising star in limnology, oceanography, and climatology, particularly interested in large-scale, ocean-atmosphere systems. He did graduate work in the Adriatic, then rose through the ranks at the Institut für Meereskunde ((IfM) Institute for Oceanography) in Berlin, leading his students on field trips to local lakes and eventually the North Sea and Baltic, where he also spent time developing and improving instruments to measure temperature and current and dynamical methods to process the data. By 1915, he had developed a theoretical conception of tidal dynamics in the North Sea that allowed him to turn the few known statistics on tidal heights into precise tidal charts for the area at the behest of the Imperial Navy, a task that occupied him until 1918. While this work remained useful to science, in that his results proved the validity of his dynamical methods, its benefit to the war effort was obvious and immediate. At the same time, he continued thermometrical work close to shore in an effort to better understand the surface interface between air and water. The relationship thus developed with the navy led to the post-war establishment of a working group involving the IfM, of which Merz became director in 1921, and the Deutsche Seewarte (German Hydrographic Office, also called the Naval Observatory) in Hamburg, to continue North Sea tidal research.[4]

The navy's own resources and personnel had obviously been thoroughly enmeshed in the war effort. In its aftermath the service suffered both the actual losses of combat and those imposed by the punitive restrictions of the Treaty of Versailles. These losses stung,

[4] Norbert Krebs, "Alfred Merz [Obituary]," *Geographische Zeitschrift*, 32. Jahrg.. 1. H. (1926): 1-6; Reinhard Hoheisel-Huxmann, *Die Deutsche Atlantische Expedition 1925-1927: Planung und Verlauf* (Hamburg: Convent Verlag, 2007), 38. For a short history of the Deutsche Seewarte's founding, see Heinrich Walle, "Die Deutsche Seewarte," *Marine-Forum: Ausgabe A: offizielles Organ der Marine-Offizier-Vereinigung* 10 (2004): 26-28. Note that Walle ignores the changes between military and civilian control of the Seewarte during the period of the World Wars.

and they were aggravated in the early 1920s by Germany's ongoing economic woes and by the loss of political prestige under the republican Weimar government for a service whose officers had been solidly monarchist.[5] Thanks in part to the large role naval troops had played in and the reactions of naval leadership to both the 1918 revolution that brought the Weimar government to power and the 1920 Kapp Putsch which attempted to overthrow it, public and government confidence in the navy remained low.[6] Because the German Peace Delegation had considered renouncing all warships before the navy took things into its own hands and scuttled most of them at Skapa Flow, historian Keith Bird has argued that the Versailles Treaty's severe restrictions may have paradoxically "saved the German navy from extinction."[7] By 1920, "[i]n government and civilian circles, a pronounced lack of faith in the navy's ability to perform even the simplest task was quite widespread."[8]

The treaty restrictions severely limited the numbers and classes of ships the navy could operate, which orphaned some unfinished new construction in the slips. Such was the fate of new construction gunboat "C", begun during the war but left unfinished, and now, because of the Versailles quotas, unfinishable as a warship. A quick-thinking hydrographer at the nautical department suggested commissioning it instead as a survey and research vessel, and the hull—moved hastily from the forfeited port of Gdańsk to Kiel—was finished accordingly, though much interior work was left to complete.[9] At heart, though, the navy was still working strategically to counter the various indignities of Versailles. Though publicly they appeared only to be shuffling survey ships—they would

[5] Keith W. Bird, *Weimar, the German Naval Officer Corps and the Rise of National Socialism* (Amsterdam: B. R. Grüner, 1977), especially 141.
[6] Bird, 9-10; 67-70.
[7] Bird, 65.
[8] Bird, 112.
[9] "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 1.

complete and keep the new vessel in place of an older one allowed under Versailles—they consciously kept open the possibility of arming it in future. And already suggestions were made within the navy for a large-scale trip abroad, to show the flag in as many ports as possible and thus project the image of a navy—and nation—that still mattered on the world stage.

THE DEUTSCHE PAZIFISCHE EXPEDITION

Oceanographer Gerhard Schott, at the Deutsche Seewarte, drafted an expedition proposal aimed mainly at the navy's desire to show the flag, with science a secondary concern. It addressed no specific scientific problem, but would use a circumnavigation to fill gaps left in the observational record by earlier voyages. In its broad, observational approach, the planned voyage would thus not have been unlike that of HMS *Challenger* fifty years earlier, and, also like *Challenger*, would concentrate significantly on the Pacific. The navy asked Albrecht Penck, Merz's mentor and, in early 1920, still his superior at the IfM, to comment on Schott's proposal and perhaps suggest an alternative. Penck delegated the task to Merz.

To a great degree, Merz agreed with the navy's concern for German visibility on the world stage, though he framed the problem through his own experience as a scientist. Without funding, limited in their access to field sites thanks to the loss of colonies, and shunned from participation in international scientific endeavors, Merz warned that German scientists would appear to be unproductive of and out of touch with first-rate science, an image that he feared would increasingly become reality as the lack of research opportunities took its toll.[10] Addressing a major, interdisciplinary scientific problem on a global scale would both prove Germans' ability to do good science and do so in a very public way. The global ocean provided just such a problem, and was itself a field site from which Germany could not be excluded by international political machinations. Merz suggested a three-year program of observations organized around a series of inter-related questions which clearly grew from his own scientific interests, including the origin of oceans and continents, the general circulation of water in the oceans and of air in the atmosphere, a clearer picture of the ocean's bottom contours and of benthic tectonic activity, and a better understanding of ocean tides and of the chemical makeup of seawater.

The navy liked Merz's proposal and commenced planning, though this preference may have laid the seeds for later contention between the IfM and Seewarte. Of primary concern was the vast distances involved—the ship would need a cruising range of between eight and nine thousand nautical miles before refueling. As currently configured, the former gunship "C"—now the research and survey ship *Meteor*—could not carry enough coal to fire its boilers over such distances, and Pacific coaling stations were few and far between, so even before the selection of Merz's plan, a naval shipyard had been tasked with considering *Meteor*'s conversion to oil-fired boilers to handle the great distances involved. Unfortunately, such a change—exchanging boilers for diesel engine, tightening the bunkers to hold oil, and changing the rig on the auxiliary sails—would increase the costs of completing the still-ongoing construction by twenty percent, or three million extra marks. The hard-pressed post-war navy simply could not manage the sum, and the Weimar

[10] On the postwar exclusion of German scientists from international scientific efforts, see Daniel Kevles, "'Into Hostile Political Camps': The Reorganisation of International Science in World War I," *Isis* 62 (1971): 47-60.

government did not share Merz's and the navy's sense of urgency for the task, given everything else left to rebuild in the war's wake. The plan for a grand "Deutsche Pazifische Expedition" was dropped. [11]

THE NOTGEMEINSCHAFT DER DEUTSCHEN WISSENSCHAFT

At the end of January 1924, Merz attended a meeting of the Notgemeinschaft der Deutschen Wissenschaft—the Emergency Committee for German Science—chaired by Prussian minister of culture Friedrich Schmidt-Ott. A non-governmental organization with a commitment to fund German science, the Notgemeinschaft had been formed in the immediate aftermath of the war by leading scientists of the Prussian Academy of Scientists, who shared Merz's fear that Germany was in danger of falling from the ranks of first-rate scientific powers. Schmidt-Ott echoed that fear at this session. He reported that he received very many requests for support, but that they did not seem to include any "really visionary ones." Merz, no doubt disheartened by the failure of the proposed Pacific expedition, assured Schmidt-Ott that such ideas existed, but that "complete hopelessness ruled regarding financing." When Schmidt-Ott insisted that funds could be found for the proper project, Merz pitched a modified version of the proposal he had offered to the navy. [12]

Since the original project had foundered on the immense distances of the Pacific, the new proposal stayed in the Atlantic, a region better known but more easily reachable. A thorough study with a close network of stations could build on the long-term studies

[11] This account of the early plans for the expedition relies on Hoheisel-Huxmann, *Deutsche Atlantische Expedition*, 7-13.

[12] "Abschrift der Aufzeichnungen von Prof.Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, Bundesarchiv-Militärarchiv, Freiburg im Breisgau, Germany (hereafter BMF).

already accomplished, and on Merz's own work on large-scale circulation, using his hydrodynamical methods. But, Merz assured Schmidt-Ott, the voyage could also incorporate the work of other leading scientists, such as Alfred Wegener's meteorology and Fritz Haber's chemistry. And understanding each of these three areas would also contribute to understanding the biology of the Atlantic, making the proposed expedition a broad effort to renew German relevance on almost every scientific front. Indeed, the navy would no doubt be interested in pursuing hydrographical investigations, since they still wanted an excuse to send their new survey ship abroad. A design to finish the ship's interior with seven scientists' cabins and a laboratory had already been drawn up, and this new plan would fit within existing fuel constraints. Schmidt-Ott was hooked, and asked Merz to write up a proposal.[13]

Merz did so, but, worried that after the earlier failure he could easily earn a reputation with the navy as a "maker of empty projects," he first approached his personal contacts in the navy seeking details of the ship's capabilities and a frank appraisal of the plan's likelihood to gain the support of naval leadership. With their encouragement, he worked up a preliminary proposal, then passed it back to them for the calculation of coal, material, food, and wage costs.[14]

The prospect of sharing costs made the proposal more palatable to both navy and Notgemeinschaft. Over the next several months, discussions sorted out the logistics of the expedition, focusing largely on whether to make one long voyage or two or more short ones, with time to process results at home in between. Chemist Fritz Haber pushed for the

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[13] "Abschrift der Aufzeichnungen von Prof.Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

[14] "Abschrift der Aufzeichnungen von Prof.Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

latter, hoping time in between would allow not only processing of results but also refinement of methods and a redirection of efforts and focus based on those results. (He also feared that participants' performance would decline on a long duration mission.) Merz, though, pressed consistently for one, unbroken trip, fearing—probably rightly—that if they once returned home, the funds for future legs would evaporate.[15]

Staffing the voyage was another point of contention, tied obviously to the planning of the research agenda but also to the jockeying of the several institutions that would contribute plans and expertise to the voyage. In addition to the Notgemeinschaft, Merz's IfM, the universities of the participating scientists, and the navy, this included the Deutsche Seewarte, which following the war had been removed from navy control and assigned to the Ministry of Transportation. Most of the scientists proposed during Merz's and Schmidt-Ott's original discussion became involved in the process along the way, suggesting ways in which their own research could be incorporated. Haber, for instance, initially asked Merz if he could rent the ship for four months for his own work; Merz instead invited him to take over organization of the expedition's chemistry work and made a pitch for the inclusion of biochemistry.[16] Erich von Drygalski, the scientist who had led the German South Polar expedition on the *Gauss* in the late 1880s and was now associated with the Academy of Science and the Geographical Society, was also invited to participate. Hugo Hergesell, who had supervised the meteorological efforts aboard Prince Albert's yacht twenty years earlier, joined to plan the expedition's meteorology. Most of these

[15] "Abschrift der Aufzeichnungen von Prof.Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

[16] "Abschrift der Aufzeichnungen von Prof.Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

scientists also served on the planning board that would become known as the Meteor Commission.

When Schmidt-Ott invited Eduard von Capelle, the former admiral who was now president of the Seewarte, to the first planning meeting of this "inner circle," Capelle immediately took offense at not having been involved from the beginning. Capelle was incensed that Merz had gone to the navy rather than through him, and—in what probably smarted more for the man who had been the wartime secretary of the Admiralty—that the navy had signed on to the plan and begun coordination with the Notgemeinschaft without consulting him either. Merz attempted to placate Capelle by assuring him that planning was still in its earliest stages, and that only the funding organizations had been involved so far. At the suggestion of Fritz Spiess, a naval captain and Merz's contact at the navy department, who would become captain of the *Meteor*, Capelle was supplied with the working proposal and included in future meetings, but the ill will thus established still simmered.[17] Capelle also supported the segmented expedition plan that Haber, and some in the navy, had proposed, providing another source of friction between him and Merz.

These differences came to the fore when the time came to identify the scientific staff. As the *Meteor*'s overhaul already included seven cabins for scientists, Merz proposed a lead scientist, two hydrographers, two chemists, and two meteorologists. The ship's doctor—who would live in naval quarters—would double as the expedition biologist, and had already begun training for this role at the IfM. All of the scientists would assist with sample collection, rather than restricting themselves to laboratory work, and the navy would train personnel as lab assistants. Merz pushed for young men,

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[17] "Abschrift der Aufzeichnungen von Prof.Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

up-and-coming scientists who could be future leaders in their fields. Though the group debated inclusion of various sub-specialities, and these were clearly tied to the coordination of specific scientific measurements and sampling in the work plan, the discussion was for the most part congenial.[18]

Though the staffing decisions were largely reached through consensus, Capelle bristled at Merz's control of the discussion. Capelle considered the expedition a postponement and revision of the previous expedition plans. He believed Merz had intentionally failed to involve him in the initial proposal and was now attempting to drive staff selection, apparently in favor of his IfM colleagues, thus attempting to push the Seewarte aside from a position it already held. Capelle accused Merz of seeming to think he was already the leader of the expedition, but, defending his institution's seniority, refused "to retreat a millimeter." He believed Merz's arrogance and empire-building made him unsuitable for the role. This brought things to a head, and Spiess, representing the navy, declared that organization's desire to go ahead and make an official decision about the expedition's leadership, so that they would know with whom to work. Merz was dismissed from the room for an hour-long debate, but ultimately confirmed as expedition leader. The staff were not firmly agreed until the expedition was finalized under Merz's preferred single-voyage plan, and then he as leader was given authority to choose personnel, though he valued the input of the other scientists on the suitability of people in

[18] "Abschrift der Aufzeichnungen von Prof.Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

their respective fields.[19] In addition to Merz, four oceanographers, a biologist, a geologist, a chemist, and two meteorologists eventually embarked.[20]

Capelle announced by letter that he and the Seewarte were washing their hands of the whole expedition, and further threatened to recommend to the government that the expedition was in fact unnecessary. This gave impetus to Merz's push for a single, longer expedition, a plan which finally won the day.[21] In the event, both an oceanographer and a meteorologist from the Deutsche Seewarte did participate in the voyage.[22]

MAKING THE *METEOR*

The *Meteor* was 75 meters long, 4 meters in draft, and displaced 1200 tons. Originally, the *Meteor*'s middle deck, between the superstructure and the stern, would have bristled with side guns. Their absence left room to accommodate the scientific staff, which had swollen by the time the disciplinary and institutional negotiations were finished. The new "residential deck" contained nine scientific staterooms, a laboratory, and a drafting room.[23] The design of these spaces was important not just for function and comfort on such a long voyage, but also for psychological reasons.[24] Among Merz's concerns when planning the ship's outfitting was that the scientists' cabins be furnished

[19] "Abschrift der Aufzeichnungen von Prof. Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

[20] "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 4.

[21] "Abschrift der Aufzeichnungen von Prof. Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

[22] These were the oceanographer Dr. Schumacher, who had actually become involved in planning with Merz early on, and the meteorologist Dr. Kuhlbrodt, who had been nominated for the position by Hergesell. "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 4.

[23] "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 6-7.

[24] Layne Karafantis, "Sealab II and Skylab: Psychological Fieldwork in Extreme Spaces," *Historical Studies in the Natural Sciences* 43, no. 5 (2013): 551-88.

with armchairs; he considered this to be "psychol[ogically] import[ant]" to the scholars. No doubt for similar reasons, he made a note to ensure he got the largest cabin. Indeed, he appears to have shared the captain's cabin, recalling the division of this space traditionally reserved for the lone commander and its implications for the importance of the scientific mission aboard *Challenger*.[25] The ship was furnished with “beautiful functional interior decor done in the most beautiful wood," and the cabin furniture was also wooden instead of utilitarian metal. It was decorated with "[a]ttractive items," including a piano and gramophone. Wood is generally avoided on modern warships for fire safety reasons, but in this case it was important not just for the comfort of the scientists or to make the space esthetically pleasing over the long duration of the cruise, but also because of the ship's ulterior mission, to show German pride abroad. The tastefully appointed interior allowed them to "exhibit this decor to the outside world” when both German expatriates and officials and scientists of recently adversarial nations toured the ship in foreign ports. The efficacy of keeping up such appearances was later clear when "[i]n the foreign press our laboratory was termed ‘a wonder of a floating laboratory.’"[26]

That wondrous laboratory, which had been "furnished according to the wishes of the individual scientists" provided chemical, biological, and geological workstations, as well as accommodations for two laboratory technicians. Each workstation was provided with fresh and salt water and electrical power, and the lab was well equipped with a

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[25] The note is in "Abschrift der Aufzeichnungen von Prof. Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF. Spiess later recalled that without Merz, "I had to live alone in my cabin for the rest of the expedition," *Meteor Expedition*, 101. (In the German original, "Persönlich hatte ich nicht allein einen treuen Freund und lieben Bordkameraden verloren, ohne dessen anregende Gesellschaft ich von nun an, während der ganzen Expedition in der Kommandantenkajüte allein leben mußte, sondern ich war auch in wichtigen Entscheidungen ganz auf mich gestellt," Spieß, *Die Meteor-Fahrt – Forschungen und Erlebnisse der Deutschen Atlantischen Expedition, 1925-1927* (Berlin: Dietrich Reimer, 1928), 95.

[26] Spiess, *Meteor Expedition*, 31-32.

chemical stove with fume extraction, three electrical centrifuges, microscopes (including a polarizing microscope), gas analysis equipment, geological elutriation apparatus, and plenty of storage cabinets, racks, and containers. The nearby drafting room provided work stations for two oceanographers equipped for titration, room for the meteorological equipment, and a drafting and calculating table for cartographic and calculating work. This room also housed the read-outs for the remote measuring anemometer, air thermometer, and water thermometer. A comprehensive map file, scientific expedition library, and a card file of known oceanographic data—compiled by Merz and his students before the trip—completed the equipment. [27] On the lower deck, a dark room was equipped to handle both still and cinematographic film, which would be used to study the flight of sea birds in slow motion, and also contained a recording apparatus for stereographic wave studies.[28]

As presented later in Captain Spiess's official account, the expedition was a curious mix of rigor and resourcefulness. The instruments were procured "in collaboration with the navy." Much of the naval equipment had come from the cruiser *Berlin*, but this was largely obsolete and required supplementation or modernization. The navy procured the necessary cables, while the oceanographic gear was arranged through the IfM. The Seewarte and the observatory in Lindenberg provided or procured the meteorological equipment, the Kaiser-Wilhelm Institute the chemical equipment, and the State Zoological Museum in Hamburg the biological equipment. Instruments developed for previous expeditions were improved, and the expedition members often developed instruments in

[27] "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 6-7.
[28] "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 6-7.

their areas of expertise, a task no doubt helped by the long lead time and relatively early identification and incorporation of team members.[29] The larger equipment was manufactured ashore, and typically by corporate—when possible German—makers. But the captain stressed their ability to improvise and make do. On a mission of such length and duration, and with resupply and repair limited by the financial resources of their sponsors, the *Meteor* personnel must necessarily be self-sufficient. The ship carried its own machine shop for major repairs; a precision mechanical workshop for instrument crafting and repair was added for the expedition.[30] A "well-trained precision mechanic" named Anton accompanied the expedition and was "responsible for maintenance of all scientific equipment and instruments"; he was replaced for the second half by someone named Krüger. [31] A glassblowing lamp allowed repair of glass apparatus. It also provided the capability of manufacturing instruments, as when a special inspection tube was prepared for measuring water visibility depth from a small boat.[32]

The upper deck above held three motor lifeboats, four sounding machines of various types, a meteorological kite winch, and special anchoring equipment designed to hold the ship fast in deeper water than ever attempted. In addition to the kites, the ship used balloons to carry instruments aloft. *Meteor* launched large rubber balloons in the same two-balloon configuration Hergesell had perfected on the *Princesse Alice II*. These

[29] Spiess, *Meteor Expedition*, 28.

[30] "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 6-7.

[31] Spiess, *Meteor Expedition*, 23.

[32] Spiess, *Meteor Expedition*, 169; "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": II. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 211.

were filled from hydrogen cylinders carried aboard, which could in turn be refilled with hydrogen electrolyzed from seawater.[33]

While no longer a gunboat, the ship carried one gun: a "wind gun", designed to shoot a smoke cartridge to altitudes as high as 7500 meters, allowing observation of wind speed and direction when clouds prevented the tracking of pilot balloons for the purpose. This "air shooting" eventually stopped because the vibrations it induced affected the deep-sea thermometers, rendering oceanographic measurements at a station where meteorology was also done unreliable. The ship also carried projectile guns and harpoons, which were later used from a small boat in an attempt to catch a whale; at this the unpracticed crewmembers had no success.[34]

If *Meteor*'s outfitting reflected the balancing act the navy was playing with the requirements of Versailles, it demonstrated as well the commercialization and corporatization of science in the first decades of the twentieth century. Its instruments came from commercial makers; where the *Challenger* and Monagasque instruments had borne the names of individual scientists who innovated their designs, the *Meteor*'s instruments often bore company names. These were, whenever possible, Germany companies. The photographic instruments and film were donated to the expedition by the Aktiengesellschaft für Anilinfabrikation, better known as Agfa.[35] *Meteor* carried two new echo-sounding devices; the expedition would mark the first concerted effort to echo-sound a wide area of the ocean. One was of completely German origin, developed by the

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[33] "Abschrift der Aufzeichnungen von Prof. Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF; Spiess, *Meteor Expedition*, 67.

[34] Spiess, *Meteor Expedition*, 67, 155. This too is evidence of Albert's influence on the sorts of research considered appropriate to the lone research vessel.

[35] Spiess, *Meteor Expedition*, 393.

Kiel-based Signalgesellschaft and thus named the Signal sounder, while the other was a product of the Submarine Signal Corporation in Boston, Massachusetts, sold to the Atlaswerke in Bremen. The latter equipment was renamed the Atlas sounder, despite being of American origin and barely having even been tested by the Germans before its last-minute deployment.[36]

To back-up and verify the state-of-the-art echo sounders, *Meteor* carried two line sounders: a Thomson sounding machine, originally developed by Lord Kelvin in the 1870s, and a Lucas machine, designed in the 1880s. *Meteor*'s sampling lines used reversing thermometers and messenger-operated sampling gear that would not have appeared unfamiliar to earlier expeditions. Merz's North Sea tidal work had involved development of instruments, including tidal current meters, so these home-made instruments were deployed alongside their commercially-developed cousins.[37] Thus for both technological and budgetary reasons, the expedition, as Spiess put it, "had a strange combination of old and new on our ship. While on one side she had sailing arrangements and old model drive, on the other hand she had the most modern equipment on board: gyrocompass, radio direction finder, echo sounder—a mixture of the oldest and the latest."[38]

ASSEMBLING THE EXPEDITION

Between the delays of war and of finances, *Meteor* was finally placed in commission in November 1924, officially the first new German naval vessel constructed

[36] Sabine Höhler, “Depth Records and Ocean Volumes: Ocean Profiling by Sounding Technology, 1850-1930,” *History and Technology* 18, 2 (2002): 140.
[37] Krebs, "Alfred Merz [Obituary]."
[38] Spiess, *Meteor Expedition*, 63.

since the war, but ten years and nine months after its construction had begun.[39] This long-delayed completion allowed many physical changes to the ship as it was adapted and readapted for its evolving mission. The working and living accommodations for scientists was just one aspect of this. Another major one was the ongoing evolution of the propulsion systems. With the abandonment of the planned diesel conversion, the ship retained its auxiliary coal-fired steam system. In order to increase range, two of the four original boilers were removed and replaced with enlarged bunkering capacity.[40]

The ship got underway for sea trials, which were conducted as a kind of preliminary expedition in the North Atlantic for six weeks from January to March 1925. The inclusion of this voyage in the expedition's official scientific account in the journal of the Geographical Society of Berlin marks an interesting difference from the reports of its predecessors, though it probably occurred because the overview section of the report was written by Spiess rather than one of the scientists. As the *Porcupine* and *Lightning* had for *Challenger*, and Prince Albert's unreported sea trials had for his yachts, the preliminary expedition served an important purpose for *Meteor*, serving as an extended "shakedown cruise" for equipment, personnel, and working relationships. The novel deep water anchor was tested, and its handling mechanisms found insufficient for the task. Shortcomings were also found in water sampler closures, current meter strength, and insulation of the laboratories and scientists' staterooms. Details were wired home by telegraph so the shipyard could begin to prepare fixes. In keeping with the corporate nature of the instruments, company technicians accompanied the ship on the preliminary

[39] Hoheisel-Huxmann, *Deutsche Atlantische Expedition*, 20.
[40] "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 9.

expedition, allowing on-the-spot repair or at least expert understanding of problems experienced. [41]

Once the ship returned to Wilhelmshaven, the yard got to work addressing the problems uncovered. Coal consumption continued to exceed expectations, imposing a range limitation that could become problematic. Little more in the way of substantive changes could be made to the boilers, so the naval shipyard addressed the problem through creative tweaking of all the other technologies involved: A smaller, auxiliary boiler was added for in-port use. This would result in a reduction of coal consumption as well as allowing downtime for maintenance to the main boilers. A new diesel generator would power shipboard electrical systems and further reduce coal consumption. Two meters height were added to the smokestack, improving exhaust gas flow and simultaneous improving conditions on deck, where the scientists had discovered ash and flue gases interfered with their work. Propeller efficiency was improved. At the same time, the ship's sailing rig was modified, provided a full-rigged forward mast with three square sails. To accommodate the remaining shortfall in cruising range, a petty officer's cabin was converted into an additional coal bunker, adding 60 tons capacity, and storage space was found on deck for another 50 tons. *Meteor* now carried 440 tons of coal, providing a theoretical steaming range of 6800 nm.[42]

The long lead time caused by the expedition's shaky financial start had also allowed both scientists and naval personnel to prepare quite thoroughly. As mentioned above,

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[41] F[ritz] Spiess, "Bericht des Expeditionsleiters," in "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff 'Meteor': I. Bericht," 1-24, *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 9.

[42] Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 9; Hoheisel-Huxmann, *Deutsche Atlantische Expedition*, 25-26.

Merz and his students set about assembling all known previous hydrographic observations into a comprehensive card file, as well as preparing currents maps and salinity and temperature sections from known data. Meanwhile, various naval personnel were able to get special training to allow them to undertake, or at least assist with, scientific assignments of their own. In addition to the ship's doctor training in biology at the IfM, ship's officers were assigned responsibility for astronomical and geomagnetic work, photography and cinematography, and the measurement of electrical potential. Ship's personnel also operated the sonar equipment, rapidly becoming experts in the new technology. Senior non-commissioned officers were assigned as assistants and draftsmen for the oceanographic work, chemistry, and meteorological kite and balloon handling.[43] Six non-scientist civilian employees also embarked, including the aforementioned Anton, though their identities and roles are poorly recorded,. The other five, not listed with either scientists or naval crew in Spiess's expedition reports, likely filled similar roles as "invisible technicians."[44] Crew, and occasionally scientists and officers, were traded out at various points in the voyage whether due to illness or regular duty rotation. In Cape Town, South Africa, in April 1926, before beginning the equatorial profiles, Spiess hired nine black Africans to work as stokers and scrubbers in the engineering spaces; these men appear in sailors' uniforms alongside the crew in at least two photographs, but their names are unknown. Spiess did not mention them in his official account.[45]

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[43] “Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht.” *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 7.

[44] “Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht.” *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 7. For invisible technicians, see Steven Shapin, “The Invisible Technician,” *American Scientist* 77, 6 (1989): 554-563.

[45] Hoheisel-Huxmann, *Deutsche Atlantische Expedition*, 32. For photos, see ibid, Abb. 64, and "Messkarten und Fotos von der Arbeit des Vermessungsschiffes 'Meteor'", N167-2, Auftrag Nr. 729, BMF.

Spiess reported consistent professional behavior and no strain between the various groups of personnel beyond that expected among any large number of human beings constrained to close quarters over an extended period. However, very little exists with which to check this claim: The Meteor Commission kept tight control on publications, reserving ownership of all output except the hydrographic products belonging to the navy.[46] This was not unprecedented, but it meant that this expedition did not spawn the plethora of unofficial accounts that followed the *Challenger* Expedition.

The expedition suffered a major leadership challenge when, after the first leg of the journey, Merz fell ill with lung problems; he first tried to remain on board to supervise the oceanographic work from his sickbed, but soon had to be returned to Rio de Janeiro, the nearest port, where he was treated at the German hospital. The expedition proceeded without him, with Spiess in nominal command of both ship and science, until a telegram six weeks later informed them of Merz's death. The scientists apparently asked Spiess to retain scientific leadership, a decision with which the commission in Germany eventually concurred.[47] It is unclear if this was an arrangement that had been discussed in advance. Merz had a history of illness, but the commission had decided to let him evaluate his own fitness for the long voyage; perhaps, whether because of this history or simply because travel at sea and to foreign ports involved certain risks even for the healthy, they had

[46] This policy is discussed in numerous places, among them Albrecht Penck to Spiess, 9 October 1925, N167-16, Auftrag Nr. 729, BMF. A four-page document outlining the principles under which the expedition results would be published was drafted after discussion amongst the principals; "Grundsätze für die Aufbau und Umfang des wissenschaftlichen Expeditions-Werkes der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

[47] Spiess reports being approached by Hentschel and Reger, the "two oldest scientists," Spiess, *Meteor Expedition*, 130. The committee's endorsement was conveyed by letter. Penck to Spiess, 9 October 1925, N167-16, Auftrag Nr. 729, BMF. Penck also made sure the navy endorsed the plan, as he conveyed in Penck to Spiess, 13 October 1925, N167-16, Auftrag Nr. 729, BMF.

established a plan for continuity of the mission.[48] It is also possible, considering the institutional power struggles that had occurred before the voyage, that the scientists could come to no consensus allowing one of them to step into a superior position, so the naval officer who already commanded the ship seemed a good compromise. Either way, Spiess appears to have been a good choice. He was not a trained oceanographer, but he had been involved in the planning from the beginning, and he clearly understood the work and its goals. He conscientiously continued the scientific plan to the best of the ship's ability, expressly considering Merz's original goals when modifications did have to be made.

DOING SCIENCE AT SEA

The oceanographic work of the expedition was organized around stations, as had become the standard for oceanographic work. These 300 sampling points were arranged along fourteen latitudinal cross-sections of the Atlantic, called "profiles," ranging from about 20ºN to below 60ºS. At the end of each profile, the ship would visit ports along the South American and African coasts, allowing time for replenishment and repair, but also crew leave, scientific expeditions ashore, visiting with local scientific and political connections, and other activities. The profiles had been planned according to expected climatic conditions over the course of the two-year expedition, visiting the furthest southern latitudes, for instance, during the southern hemispheric summer, and accounting for seasonal variations in the trade winds elsewhere. Echo sounding and some surface and meteorological work continued at and between stations.

[48] On Merz making the fitness decision, "Abschrift der Aufzeichnungen von Prof. Dr. A. Merz über die Verhandlungen bei der Planlegung der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

Occasionally the scientists undertook short, exploratory trips ashore, usually matters of personal rather than professional curiosity. They also organized cooperative efforts with local scientific authorities in the countries they visited, but these were valued more for the goodwill and political capital they generated than for their scientific contributions. This contrasts markedly with the work of the *Challenger*, where one naturalist soon tired of working at sea and spent most of his time working on the results of his island-based specimen collecting. Prince Albert's work, too, frequently involved coordinated shore and sea components. Meteor's post-expedition publication plan, however, even specified that "[o]bservations made on land should be taken into account only insofar as they related to the research at sea."[49]

At sea, a typical station involved the lowering of numerous thermometers and sample bottles via a large winch on the aft deck; another winch forward was available as a backup. Each carried 8000 m of aluminum-bronze stranded wire rope, with a high tensile strength and an 830-kg breaking strength. The aluminum-bronze alloy meant the line required no grease to prevent corrosion. The sample bottles were spaced along the line at intervals, their number determined by the depth, and each could be triggered in sequence by a falling weight to capture 1.25 liters of seawater. A four-liter bottle at the bottom was rigged to sample seawater with no contact with metal.[50] Once preliminary contamination checks were done, the samples were secured for further analysis in port, where chlorine titration—conducted by one of the scientists or a crew member trained for the task—allowed the calculation of salinity. The lines carried reversing thermometers, both pressure-protected and unprotected, at the same points as the water samples. Once the

[49] "Grundsätze für die Aufbau und Umfang des wissenschaftlichen Expeditions-Werkes der Deutschen Atlantischen Expedition," N167-19, Auftrag Nr. 729, BMF.

[50] Spiess, *Meteor Expedition*, 94-5.

line reached the desired depth, it would be left for twenty minutes for the thermometers to register accurately, and a messenger weight sent down the line would trigger both the water sample capture and the thermometer's reversal, locking the temperature reading at depth. The resulting temperature and salinity data together provided useful information about the movement of water throughout the ocean, while the comparison of the protected thermometer with the unprotected, which was thus affected by pressure, provided a calculated depth based on the known effect of pressure on temperature and the regular increase of pressure with depth, which could double-check the sounding line. The thermometers could be calibrated in port with a bucket of ice water. To check that the water samplers closed at the desired depth, the resulting samples were analyzed for their hydrogen ion concentration, as that too varies regularly with depth. [51]

Much of the water in the large bottles—1,282 samples in total—was intended to allow the very precise measurement of the precious metal content of seawater. This pursuit was central to the chemical program Haber had designed; his hope was that gold could be distilled from seawater to erase the massive war reparations imposed by the victors at Versailles, which were wreaking havoc with the German economy.[52] Immediate onboard analysis caught instances of contamination, allowing resampling while still on station. [53] In the case of the precious metal samples, the onboard analysis proved inconclusive, leading to the shipment of the samples back to the Kaiser-Wilhelm Institute in Berlin, where further analysis proved Haber's dream elusive. Sampling found the gold content of seawater to be about 10^{-9}g/kg, or, as Spiess noted, "one hundred-thousandth part of a

[51] Spiess, *Meteor Expedition*, 96, 99.

[52] Ralf Hahn, *Gold aus dem Meer: Die Forschungen des Nobelpreisträgers Fritz Haber in den Jahren 1922-1927*. (Berlin: Verlag für Geschichte der Naturwissenschaften und der Technik, 1999), 33.

[53] Spiess, *Meteor Expedition*, 95.

milligram," and thus distilling it from the water would cost far more than it gained.[54] Seawater would not be the answer to Germany's financial woes.

The *Meteor* did not employ a dredge or trawl, like those the *Challenger* scientists had so relied on, no doubt in part because the expedition's focus was not biology, as its predecessors had been. However, expedition personnel did take bottom samples and did some biological work incident to their work on ocean currents. Bottom samples were taken using a core sampler modified from an older Ekman model and the Lucas sounding machine. A 1.5-meter, cylindrical steel tube containing a glass tube was attached to the 10-km piano wire of the Lucas sounder, and dropped into the sea with a 30-kg sink weight, which was sufficient to ram it into the bottom upon contact. A spring which sensed that contact stopped the drum from which the sounding line was paying out, and the sounding depth could be read before retrieval. Unlike some earlier samplers, the weight was raised with the tube, allowing its reuse and thus obviating the need to haul disposable weights; Spiess calculated that over the course of the trip this saved them the need to carry 12,000 kg of weights. The tube was closed on the bottom to prevent loss or contamination of the sample, which returned not only bottom material but also the water in contact with it. When it reached the surface, the glass tube was removed from the steel one and sealed with rubber corks at each end. Bottom core samples averaged greater than 50 cm in length, with some exceeding 90 cm. In bottoms too sandy to successfully secure a core, a grab sampler was used, which enclosed a four-liter bottom sample in two bowl-like scoops. The glass tube allowed viewing of the sample's stratification before its removal. It was then cut in half lengthwise, with half retained for analysis onboard while the other half was

[54] Spiess, *Meteor Expedition*, 353-354. As Haber put it, "Die Aussicht auf eine Nutzbarmachung des Meerwassers zur Goldgewinnung ist geschwunden." Quoted in Hahn, *Gold aus dem Meer*, 80.

secured in paraffin for analysis in Germany. Color, oxidation, calcium content, and particle size analysis allowed the scientists to compare bottom sedimentation with their onboard plankton sampling and to integrate geology into their study of currents.[55]

Because of the need for multiple water and temperature samples over great depths, a station usually involved the taking of three series of samples, one shallow, another at middle depths, and a third deep. Merz had estimated each station would take ten to twelve hours, but with practice they averaged eight to nine, and as few as six when the weather was fine. Meanwhile the biologists performed net catches on the surface and in shallow water.[56]

The bulk of biology work on the voyage consisted of plankton studies. Plankton counts were performed on the water samples gathered during the sounding series. Nanoplankton, especially, were too small to catch with even a fine silk net and thus must be centrifuged from water samples and then counted and examined under a microscope. Over 1200 such samples were examined while at sea, demonstrating that plankton lived even at depths of 4000 or 5000 meters, and that their numbers were greatest where cold Antarctic water mixed with warm.[57]

Larger plankton were captured from near the surface using one of two pumps which pulled from between 50 and 100 meters depth. The water was directed into a barrel, then filtered through a net of fine plankton gauze. Actual net catches were also made with the Lucas sounding machine and either an Apstein or Nansen net. The former, shaped like a funnel, filtered water towards a measuring cylinder where plankton accumulated on a piece of parchment paper. The latter directed water towards a bottle; the apparatus was sent

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[55] Spiess, *Meteor Expedition*, 153-155.
[56] Spiess, *Meteor Expedition*, 99.
[57] Spiess, *Meteor Expedition*, 124-5.

down open to a predetermined depth, then hauled up until a second chosen depth where it was closed by messenger before being lifted to the surface. In both cases, the collected plankton were sent to the State Zoological Museum in Hamburg, which had contributed both the biological equipment and the lead biologist.[58]

This work was done in concert with the chemical and current studies in an effort to understand the distribution of nutrients and of plant and animal life in the oceans and their relationship with oceanic currents.[59] In fact, these results would show from the paucity of nutrients in tropical surface waters compared to relatively high values below the thermocline that vertical mixing did not take place, helping to explain the lack of plankton in these nutrient-poor areas.[60] Later, these results would contribute to the explanation of spring plankton blooms during seasonal upwelling near the poles.

The biologists observed larger fauna as well, though less comprehensively. Twice a day, they conducted a quantitative bird count in the aft quadrant of the ship's view. They would also count floating and moving organisms, such as jellyfish and weeds, seen in this quadrant in a fifteen-minute span. Lookouts were trained to call the biologist immediately if any unusual plant or animal was sighted; obviously this means the sailors were trusted to know what was usual in any given area of the ocean. Occasionally, the biologists on board took advantage of opportunities to examine large specimens in close quarters. For instance, while at anchor on the western side of the Mid-Atlantic Ridge during the second profile across the Atlantic, a 90-kg blue shark was caught and dissected by a biologist.[61]

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[58] Spiess, *Meteor Expedition*, 124-7.

[59] Spiess, *Meteor Expedition*, 124.

[60] Eric Mills, *Biological Oceanography: An Early History, 1870-1960* (Toronto: University of Toronto Press, 2012), 160.

[61] Spiess, *Meteor Expedition*, 123.

And as has been mentioned, slow-motion film studies were made of albatross in order to study their flight.

Meteorology formed a major area of research both in its own right and in concert with the oceanographic studies, to elucidate the role of winds in the development of surface currents. The normal, daily observations of the crew continued, recording meteorological conditions hourly in the ship's logbooks and daily observation books. The two embarked meteorologists made similar but more extensive observations of surface air pressure and temperature, atmospheric humidity, surface water temperature, cloud forms and coverage, surface wind direction and strength, evaporation rate, and visibility. These were taken regularly three times a day, at 7 AM, 6 PM, and 9 PM. Spiess noted that the ship was well equipped to make these observations, which were "identical to those obtained by the first class meteorological observation station on land." The observations were radioed home as well as recorded. On the preliminary run, crewmen discovered that the thermometer on the bridge read falsely high because of its proximity to the metal bulkheads. A series of remote thermometers were set up for comparison, located on the bow, stern, and at the top of the foremast in order to be as far from heat sources as possible. All four could be read in the drawing room.[62]

The meteorologists also measured solar radiation with a pair of actinometers, though Spiess reported that the deck of the ship proved not to be ideal for the purpose because these must remain focused on the sun during a reading. The instruments were also difficult to keep in a smoke-free place on the coal-burning ship. One of the

[62] Spiess, *Meteor Expedition*, 64-65. Quote is on p. 64.

meteorologists constructed a recorder for measuring total radiation, though, which was placed on the aft deck.[63]

The meteorologists studied the upper atmosphere in accordance with Hergesell's plan, and thus in much the same way Prince Albert had over the previous several decades. Twice a day, unless cloud cover obscured visibility, the crew released and tracked pilot balloons to observe winds aloft. The large, rubber balloons, perhaps 1.5 meters in diameter, reached heights of up to 21,000 meters before bursting. On cloudy days, the wind gun provided an alternative tool for visualizing and tracking the winds until its use was stopped because of the effect of its vibrations on the ship's thermometers, as described above.[64]

For more detailed information, both kites and balloons could carry instruments aloft. Large box kites were launched using an electric motor and 10 km of piano wire from the aft deck, though the crew had to develop procedures to handle them in the small space available. The main kite carried a "meteorograph," an instrument package which recorded temperature, air pressure, moisture, and wind velocity. As the main kite rose into the air, up to five or six auxiliary kites could be attached to the line to provide additional lift, allowing the heavy package to be carried as high as 4 km. Kites were launched "in even slightly favorable conditions" and could even be launched on brightly moonlit nights and tracked by searchlight. Once in the air, they were controlled and retrieved using a smaller, hand-operated winch. The kites were highly stable aloft, but

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63 Spiess, *Meteor Expedition*, 66.
64 Spiess, *Meteor Expedition*, 66-7.

they were difficult to retrieve in a strong wind and might sometimes dive into the sea at the last moment and be lost.[65]

Paired balloons allowed the study of meteorological conditions at higher altitudes. As on Albert's yachts, a main balloon, filled to capacity with hydrogen, carried the meteorograph in a basket, while a secondary balloon with a lesser hydrogen charge tagged along for the ride. The gas within the balloons expanded with decreasing atmospheric pressure until the fuller balloon burst at about 20 km altitude. The second balloon, unable to keep the instrument package aloft by itself, nevertheless acted as a parachute to slow its descent, and then as a beacon to mark its landing spot upon the surface so that the ship, which had been tracking the entire flight, could retrieve it.[66] These flights were carried out less often than the kite ascents, in part because the tethered kites could safely ascend into clouds, whereas a heavy cloud cover that obscured tracking of the free-floating balloons could result in the loss of the instrument package.

SOUNDING THE OCEAN

The most revolutionary of the technologies *Meteor* applied to studying the oceans was sonar, in the form of an echo sounder or fathometer. Echo sounding had been proposed as a means of depth-finding quite early; by 1858 Matthew Fontaine Maury reported that a number of methods had been tried, including the use of explosives or bells to create the sound signal, but "out in 'blue water' every trial was only a failure repeated."[67] A device to find depth by using a sound pulse had been patented in Germany as a

[65] Spiess, *Meteor Expedition*, 67-9, 287. Quote on pg. 69.
[66] Spiess, *Meteor Expedition*, 53-54.
[67] Matthew Fontaine Maury, *The Physical Geography of the Sea,* 6th ed. (New York, 1858), 243-244.

navigational device as early as 1912, and in the wake of the *Titanic* disaster inventors and maritime officials experimented with the same concept to measure distances horizontally or find objects (such as icebergs) in the water surrounding a vessel. The Great War's interference in civilian shipping had retarded the spread of the navigational technology and obscured much of the other experimentation beneath the cloak of military secrecy. By the 1920s, though, the US, France, and Britain all experienced some success in developing these tools and were deploying them in limited fashion aboard moving ships. An American warship had sounded a continuous profile across the Atlantic, and while the resulting single depth cross-section demonstrated that such a feat could be accomplished, it hardly cast more light on the topography of the Atlantic basin than had Maury's few dozen scattered line soundings. In 1923 the US hydrographic office published a bathymetric chart of the California coastline incorporating 5000 sonar measurements conducted by two warships over thirty-eight days, but even this, as Gerhard Schott noted, while it represented a vast improvement both in area covered and in time and labor spent, barely touched the rim of the vast Pacific.[68]

In addition to the Signal and Atlas sounders described above, *Meteor* carried two iterations of earlier acoustic sounders. The Behm sounder worked essentially along the principles Maury and others had suggested; a blast cartridge detonated at the surface, sending a pulse of sound into the water and starting a timer which was stopped by the returning echo. It was only useful to 750 m, and even then was not terribly accurate. The free sounder, also known as the bomb sounder, was another product of the

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[68] Höhler, "Depth Records," 136; "Echo Sounding: Test carried out by the U.S.S. 'Stewart' 20th to 29th June 1922," *Hydrographic Review* 1 (1923): 71 – 72; Schott, "Tiefseelotungen mittelst Echolot," *Annalen der Hydrographie und Maritimen Meteorologie: Organ des Hydrographischen Bureaus und der Deutschen Seewarte* 51 (August 1923): 192-195.

Signalgesellschaft. It used the direct sound of an explosive, rather than its echo, to measure depths in fairly shallow water (less than 200 m). An explosive designed to fall through water at a constant rate was released, and its descent timed until it exploded upon contact with the bottom. The duration of its descent allowed calculation of water depth, ignoring the speed of sound in such shallow depths. [69]

The two new, state-of-the-art sounders, though, promised much more precise measurement, and the Germans hoped to provide the first comprehensive survey of the Atlantic. The Signal sounder was successfully tested during the trial expedition, but the Atlas was not ready in time, and thus went directly into service during the main expedition. Both operated by the emission of a 1050 Hz sound pulse, which reflected off the bottom and returned to the ship after a delay which depended on the depth beneath the ship's keel. The reflected signal was detected by a receiving membrane on the hull. The sounding apparatus calculated the depth automatically based on the delay, using a preset approximation of the speed of sound in seawater.[70] Soundings could thus be conducted in any depth, in all weather, while the ship maintained speed. At every oceanographic station, an old-fashioned line sounding verified the echo sounding results.[71]

In addition to the receiving membrane on the hull, the returning echo was also picked up by a microphone and conveyed to listening naval personnel. Schott, at the Seewarte, believed the automation that allowed the calculation of depth without human intervention, and thus elimination of the human ear from the process, rendered the method

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[69] Hoheisel-Huxmann, 58.
[70] This was 1470 m/s for the Signal sounder, or 1490 m/s for the Atlas. Hoheisel-Huxmann, 58.
[71] Spiess, *Meteor Expedition*, 151.

more objective and thus its results more accurate and trustworthy.[72] The technicians doing the listening, though, found that with practice they could distinguish bottom type and topography based on differences in the reflected sound. They could also hear the reverberating echoes. Technicians soon learned to recognize the different sounds and patterns of reverberation returned from different bottom morphologies. On a flat bottom, the echo might repeat up to five times at regular intervals. But when the bottom was broken and irregular, the intervals were irregular and the repeated echoes might even overlap.[73] Retaining the human ear in the process thus led to results that might arguably be less precise in terms solely of depth measurement, but which provided additional layers of information granted solely through the employment of this expert sensory knowledge. The results were as good as could have been hoped. The two modern echo sounders performed flawlessly; they remained in continuous use during the thirty-month expedition with no technical difficulties, usually taking individual measurements every twenty minutes, which placed them at two or three mile intervals.[74] When the bottom topography seemed particularly interesting, the interval was shortened. The morphology thus charted often determined the location or interval of oceanographic stations, as it suggested the contours of ocean basins which could, when augmented with the thermal and chemical results gained by sampling, elucidate the movement of deep currents. The resulting charts of Atlantic topography represented a significant legacy of the expedition, and formed the

[72] Höhler, "Depth Records," 134. Schott, "Messung der Meerestiefen durch Echolot," *Verhandlungen der Deutsche Geographentages* 21 (1926): 142.

[73] Spiess, *Meteor Expedition*, 83.

[74] Spiess, *Meteor Expedition*, 83.

basis for a three-dimensional, bottom relief model of the South Atlantic displayed in the Berlin Museum of Oceanography.[75]

In addition, as historian Sabine Höhler has pointed out, the use of a sound moving through water to calculate distance rendered the water itself the medium of measurement, instead of the lines and weights of the previous generations of sounders. The properties of sea water that affected the behavior of sound within it thus became important objects of study for the purposes of their participation in this technology, rather than just as an end in itself.[76] This would prove immensely important to the future direction of physical oceanography as a field, turning the world's blue water navies into important patrons of oceanography and simultaneously guiding the direction of study as the field developed over the course of the next several decades.

CONCLUSION: MAKING GERMANY GREAT AGAIN

For a scientific study aimed at understanding global systems, the Deutsche Atlantische Expedition's agenda still managed to be overwhelmingly nationalistic. This is perhaps not surprising for its time and place. Historians have noted a push in the first few decades of the twentieth century towards internationalism in science, especially in European science. The ocean and atmospheric sciences in particular seemed highly suited for transnational work, as the winds and currents and their flora and fauna respected no national boundaries.[77] This was a goal of Maury, and of Albert, in his organization of and

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[75] Höhler, "Profilgewinn, 234-246.

[76] Höhler, "Depth Records," 122.

[77] Elisabeth Crawford, "The Universe of International Science, 1880-1939," in Tore Frängsmyr, ed. *Solomon's House Revisited: The Organisation and Institutionalization of Science*, 251-269 (Canton, MA : Science History Publications, U.S.A., 1990); Rozwadowski, "Internationalism, Environmental Necessity and National Interest in the Marine Sciences and Other Sciences," *Minerva* 42 (2004): 127-149; Jacob Darwin Hamblin, "Visions of International Scientific Cooperation: The Case of Oceanic Science 1920-1955,"

participation in international meteorological observation efforts and his cross-border correspondence and conferences. Post-Great War, the formation of the League of Nations suggested a new internationalism on the political front, one which scientists might have been forgiven for imagining would be reflected in their own situation.

However, just as the war had wrought major changes in European politics, the case for international science had also been complicated by the conflict, especially when it came to Germany. Along with their compatriots in other fields, German scientists were dealing with a swirl of both concrete and emotional repercussions from the war. This included actual privation and hardship, amplified by the hyperinflation of the 1920s; in the case of scientists this meant a lack of funding opportunities, especially outside Germany, where German currency would not be accepted because of its illiquidity. It also included censure and blame, or at least the perception of blame, from international peers and scientific bodies, who as a result did not invite German participation in international efforts. The friendly reception of the *Meteor* scientists among their Scandinavian peers suggests this was not always true on an individual basis, but German organizations were clearly and intentionally being given the cold shoulder during this period, as Daniel Kevles and others have shown, and perhaps more importantly, they perceived themselves as being left out.[78]

Neither were German scientists above the emotional fallout of the war. Many of them had invested themselves fully in the war effort, in keeping with Haber's claim that "[i]n wartime, the scholar belongs to his nation, in peacetime to mankind."[79] They

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Minerva 38 (2000): 393-423; Rozwadowski, *The Sea Knows No Boundaries: A Century of Marine Science under ICES*. (Seattle: University of Washington Press, 2002.)

[78] Daniel Kevles, "'Into Hostile Political Camps': The Reorganisation of International Science in World War I," *Isis* 62 (1971): 47-60; Elisabeth Crawford, "Internationalism in Science as a Casualty of the First World War: Relations between German and Allied Scientists as Reflected in Nominations for the Nobel Prizes in Physics and Chemistry," *Social Science Information* 27, 2 (June 1988): 163-201.

[79] Quoted in Elisabeth Crawford, "Universe of International Science, 252.

suffered a wounded nationalist pride at the same rate as their peers in other professions. As a nation, Germans had lost a war, and they suffered now from restrictions on what had been favorite nationalist projects, like the fleet Germany had worked so hard to maintain at the level of a world power, or the colonies they had scrambled to build abroad. Germany had been at the forefront of science, a leader in any number of fields. The lack of money, of colonial sites that could easily accommodate their fieldwork, and of international goodwill, meant they now risked falling behind in science, just when they had been so decisively removed from world power status politically. These concerns were reflected in every detail of the planning and execution of the Deutsche Atlantische Expedition, from the practical to the symbolic.

From a practical standpoint, the ongoing devaluation of Germany's currency was a constant backdrop to their work. This can be seen in Merz's fears that a multi-stage expedition would be cancelled after the first leg, as he imagined returning home to find funding for the next sections had evaporated. During the expedition itself, supplies—from instruments to foodstuffs and even coal—were often shipped via German cargo line to their expected ports of call so that they could be paid for in home currency, rather than having to spend scare foreign currency or gold for these expenses abroad.

From the more emotional standpoint, the planners and participants positioned themselves as inheritors and continuers of a great scientific tradition, and when possible, a specifically German tradition. This was not wholly without precedent. Certainly previous expeditions made similar nods to the footsteps in which they travelled, as Spiess did when he reported on the number of stations they made in the same locations as *Challenger* had, as at a mid-ocean station on 10 August 1925, or even when they sounded on the same spot as USS *Dolphin* had under Maury's orders over seventy years earlier. [80] Neither was he out of line to do so; the use of sonar sounding to measure the depth of *Dolphin*'s notoriously deep line sounding, thus reconfirming with the new technology the inaccuracy of the original depth, was completely scientifically appropriate. That in doing so he claimed for German science some greater mastery over the hitherto imprecisely known depth was, however, symptomatic of the entire attitude of the expedition. When Spiess cited previous expeditions, he noted pointedly that (by his calculation) seven of the ten major expeditions preceding his had been German, including those of *Gazelle*, *Möwe*, and *Planet*, and he pointed out whenever *Meteor*'s track or data intersected with these forerunners.[81] When *Meteor* reached South Georgia Island in February 1926, ship's personnel visited the site of the German station from the 1882/3 International Polar Year investigations, a visit Spiess described as a kind of pilgrimage. Appropriately to that purpose, they reported finding many remains, though it had been largely destroyed.[82]

This is not to say that the Germans distanced themselves from the scientific work of non-Germans. Spiess invoked the names of *Challenger* and *Dolphin* as tokens of power, proving *Meteor*'s worthiness for inclusion in the list of major expeditions and great ocean science. (As indeed, the *Challenger* participants had in turn painted themselves as successors of Darwin, and Maury and his lieutenants had included themselves in a narrative of great expeditions of exploration.) Similarly, Merz visited Scandinavian researchers before the expedition, seeking their blessings on the plan, and the researchers welcomed already famous Swedish oceanographer Walfrid Ekman as a guest on the

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[80] Reinhard Hoheisel-Huxmann, *Die Deutsche Atlantische Expedition 1925-1927: Planung und Verlauf* (Hamburg: Convent Verlag, 2007), 36; 89

[81] "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff "Meteor": I. Bericht." *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): [XVII] – 77.

[82] Hoheisel-Huxmann, *Deutsche Atlantische Expedition*, 47.

preliminary expedition, ostensibly to supervise the initial use of their water samplers and current meters, which were based on his designs, but clearly also seeking in his presence approbation for their efforts.[83] If Germany did science that put them in the company of great expeditions and that met with the approval of internationally known scholars, then they were a Great Power once more, in a way Versailles could not deny them.

The displays of nationalist pride were not confined to the performance of science, however, though it is difficult to tell how much of its frank display is because of the hybrid nature of the expedition's leadership, which left a career naval officer to write the official expedition account, or because that account was intended for the public rather than a scientific audience. Port calls for replenishment and refueling had been intentionally scheduled for former German colonies or major German expatriate communities whenever possible. These visits were celebrated with speeches commemorating Germany's past and predicting its future greatness, and with patriotic songs, such as when they concluded a celebration in Windhoek with a rousing rendition of "Siegreich woll'n wir England schlagen!" ("We want to defeat England!") in the presence of British officials. Spiess followed with a speech, telling the crowd, "Germany has always risen again. What it needs is the right man and he will come!"[84]

While it is perhaps unsurprising for logistics and public relations, which so clearly encompassed the swirl of both concrete and emotional repercussions from the war, to express a nationalist agenda, the expedition's scientific activities were not exempt, as Merz's initial promise to lay claim to the Atlantic suggests. Höhler has argued the

[83] F. Spiess, "Bericht des Expeditionsleiters," in "Die Deutsche Atlantische Expedition auf dem Vermessungs- und Forschungsschiff 'Meteor': I. Bericht," 1-24, *Zeitschrift der Gesellschaft für Erdkunde zu Berlin*, 5/6 (1926): 9.

[84] Spiess, *Meteor Expedition*, 271.

gathering of oceanographic and sounding data—and their publication by German scientists in charts of the ocean's basin which were labelled as products of German science—constituted a symbolic claiming of territory.[85] If Germans could no longer claim colonies ashore, they could, in the act of mapping, claim the bottom of the ocean.

I would suggest their meteorological efforts similarly laid claim to the currents of the air over the Atlantic. While the meteorologists onboard both wrote their own reports and sent data home for further analysis, much of their results volume consists of hundreds of pages of tabulated data, an assertion of German data dominance to support the symbolic seizure of aerial territory. Spiess also noted, "The total aerological data [from the voyage] will be of great practical value for aviation over the Atlantic Ocean, which cannot be long in coming."[86] Indeed, Charles Lindbergh's transatlantic flight drove this message home, just two weeks before *Meteor* at last returned home to Wilhelmshaven in early June 1927. Although Spiess did not explicitly tie this prediction to military purposes, the statement—and the studies it represents—must be considered alongside other forms of German pushback against mandated disarmament. Just as the encouragement of soaring in gliders allowed the nation to train a cadre of pilots without building powered aircraft, so too would the scientific study of the atmosphere over the Atlantic have great usefulness for a revived military machine.[87]

The German Atlantic Expedition, then, demonstrates the not uncommon trope of science as a tool of politics. But these scientists were neither naïve pawns of savvy

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[85] Höhler, "Profilgewinn," 234-246. In this article and elsewhere, Höhler's argument follows Bruno Latour's depiction of the collection of data into charts as a rendition of time and space into stable but portable form; Höhler, "Depth Records."

[86] Spiess, *Meteor Expedition*, 391.

[87] Peter Fritzsche, *A Nation of Fliers: German Aviation and the Popular Imagination* (Cambridge, MA: Harvard University Press, 1992), especially ch 3, "Gliding and the Revival of Nationalism," 103-131.

politicians nor cynically trading their support for naval goals in exchange for access to resources for their work. They were instead willing wielders of politics, as eager to use their skills to forward German pride and to defend their perceived place in the first rank of a worldwide hierarchy as were their naval colleagues. This model of the relationship between science and the state is a useful one to keep in mind. It is likely also a more common one than many might prefer to imagine.

It also shows that there is nothing inherently international about the ocean or about ocean science. Where these might seem an obvious field for international effort, they just as easily provide a space for the exercise of national political power. Either use relies on the contingencies of human agency.

CHAPTER 5: Biological Oceanography and the R/V *Alpha Helix*

> *"To Scholander, the* Alpha Helix *is an opportunity for seeking out the brightest available minds, telling them in effect: 'Have lab, will travel,' and inviting them along."*
>
> -- Daniel Behrman[1]

The R/V *Alpha Helix*, funded in 1962 by National Science Foundation (NSF) grants and launched by the Scripps Institution of Oceanography (SIO) in 1965, was the most celebrated and successful of several research vessels for biological oceanography built or converted in the 1960s. When SIO physiologist Dr Per F. Scholander conceived of a research vessel that would allow him and his fellow biologists to conduct a focused and well-equipped study of marine organisms in the field, he envisioned more than a scientific instrument—the *Alpha Helix* would serve as a social and disciplinary tool, a focal point for the collegial interchange and networking of scientists from a variety of experience levels and a number of interrelated biological disciplines. "Built places," as sociologist Thomas F. Gieryn has pointed out, "materialize identities for the people, organizations, and practices they house," and this is as true for the laboratory ship as for the laboratory buildings Gieryn was examining.[2] Biological oceanographers inhabited a disciplinary and funding world that consistently sidelined them, and *Alpha Helix* was one of several efforts they made to place themselves at the planning table.

To do so, Scholander and his allies mustered not only the assembled influence of colleagues in the biological sciences, but also the language of physics—latching on to depictions of research ships as the cyclotrons of oceanography—and the administrative

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[1] Behrman, *The New World of the Oceans: Men and Oceanography* (Boston: Little, Brown, 1969), 31.

[2] Thomas F. Gieryn, "Two Faces on Science: Identities for Molecular Biology and Biotechnology," ch 20 in *The Architecture of Science*, edited by Peter Galison and Emily Thompson, 423-455 (Cambridge, MA: MIT Press, 1999), 423.

power of SIO, despite that institution's own focus on physical oceanography. With this support, Scholander and his allies laid the framework for a broad understanding of the biological ocean sciences as all belonging, so to speak, in the same boat, and he asserted their worthiness of consideration as equals in a discipline that demanded adventure as a path to recognition. This, as much as providing a mobile laboratory, was the purpose of the *Alpha Helix*. The importance of considering technology in the performance of science thus seems especially acute in the case of a ship like *Alpha Helix*, which was designed from the keel up by a specific scientist to meet his specific requirements—both scientific and symbolic—in the context of the interdisciplinary scramble for funding in postwar American science.

OCEANOGRAPHY IN POSTWAR AMERICA

Before World War II, oceanographic research was largely concerned with the biological aspects of the sea, though many scientists were calling for broader definitions. This emphasis grew from several factors. One lay in the origins of the two major oceanographic centers: Woods Hole Oceanographic Institution (WHOI) on the East Coast and SIO on the West both grew from or in the shadow of long-established marine biological stations and thus retained a strong emphasis on biology. A second factor was access: the depths of the sea could be studied only at a distance. While measurements of depth, salinity, temperature, and current were of course possible, and collected prolifically, marine life had throughout history been the most accessible and tangible aspect of the sea, whether gathered by ship or along the shore.[3]

During the interwar period in the United States, the interest of the largest patrons lay in fisheries science. The single most important funding source for biology in academia as a whole was the Rockefeller Foundation, which had already begun to develop an interest in "increas[ing] the ability to derive food from the sea." The ocean sciences were among its beneficiaries, including the grants that established and endowed WHOI in 1930 and those that funded the work of biologist Claude E. Zobell at SIO from 1930.[4] SIO's largest source of outside support before World War II came from the state of California and the California fisheries industry.[5]

During this same period, though, physical oceanographers and their fellow physical scientists in disciplines that were increasingly agglomerated as oceanography engaged in active efforts to define their field and to seek out opportunities to promote it. One fruitful approach was to align their scientific program with the needs of and opportunities provided by the US Navy. Recognizing in the urgent need for submarine detection technology during World War I a potential area of mutual interest between ocean scientists and naval officers, physical scientists proposed cooperation after the war. This partnership blossomed in World War II, when the global proliferation of newer, quieter, more sophisticated submarines made detection even more important to national security. In

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[3] For an overview of scientists' increasing access to and thus understanding of the deeper ocean during the nineteenth century, see Helen M. Rozwadowski, *Fathoming the Deep: The Discovery and Exploration of the Deep Sea* (Cambridge, MA: Belknap Press, 2005).

[4] Tom Rosenbaum, Rockefeller Foundation, personal communication to the author, 16 May 2012; Toby Appel, *Shaping Biology: The National Science Foundation and American Biological Research, 1945-1975* (Baltimore: Johns Hopkins University Press, 2000), 11; Gary E. Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment* (College Station: Texas A & M Press, 2001), 50.

[5] Ronald Rainger, "Constructing a Landscape for Postwar Science: Roger Revelle, the Scripps Institution, and the University of California, San Diego," *Minerva* 39 (2001): 341.

addition to studying underwater sound propagation for antisubmarine warfare, physical scientists addressed questions of surf and swell prediction and other meteorological issues vital to the amphibious landings that played so prominent a role in the war.

The physical oceanographers had effected quite a coup, overturning the prewar disciplinary hierarchy that had, in their minds, left them unfairly neglected in favor of biologists. The wartime projects, and those foreseeable at its end, involved physical oceanography, marine geology, meteorology, and chemical oceanography—there was little sign of the life sciences. Indeed, a table prepared at SIO in 1945 listing nine areas of scientific study which could benefit the navy included "Biology and chemistry" only in last place, and that only in the context of preventing "Fouling and corrosion," rather than better understanding the ocean itself. That the biggest contribution the life sciences might be expected to make was in developing ways to prevent marine life from growing was ironic but telling.[6]

An episode from this period showed biologists what they might expect in the new funding atmosphere. Microbiologist Claude ZoBell and ichthyologist Carl Hubbs, both at SIO, proposed a trans-Pacific expedition (TRANSPAC) to transport as many scientists as possible to the 1953 Pacific Science Congress in Manila while allowing them to perform science in a little-studied region along the way. The National Research Council lauded the plan, pointing to the reopening of international scientific ties broken by the recent war and adding the hope that the expedition would demonstrate support for the regionally important oceanographic institute in Nhatrang, Vietnam, then facing its own funding difficulties. Roger Revelle, a physical oceanographer who had spent the war in uniform

[6] Rainger, "Adaptation and the Importance of Local Culture: Creating a Research School at the Scripps Institution of Oceanography," *Journal of the History of* Biology 36, no. 3 (2003): 490.

before returning to become director of SIO, arranged funding from the Office of Naval Research (ONR), but this agency quickly inserted itself in the planning process, pointing to the navy's need for data from further north in the Pacific. TRANSPAC soon became a largely physical science expedition, with few biologists onboard, on a route more useful to the navy than to the original scientists. Both the visit to Nhatrang and the transport of scientists to the congress, the original purpose of the proposed expedition, fell by the wayside.[7]

Luckily for biologists, other governmental organizations were interested in oceanographers. The mutual enthusiasm generated between scientists and officials by government funding of highly successful science during the war inspired proposals from Vannevar Bush and others that culminated in 1950 with the founding of the NSF, an organization aimed at funding basic research across the sciences. NSF quickly became aware of the underrepresentation of basic life sciences among the available funding sources. The new Division of Biological and Medical Sciences (BMS) was the first division established within the foundation, resulting in NSF's entire first year of grants going to biologists.[8]

One of the guiding principles of BMS was an effort to consolidate biology into a single, broad discipline at a time when university departments were typically segregated along subdisciplinary lines, such as botany, zoology, and the like. Upon its creation, BMS was organized into seven programs along functional, rather than disciplinary, lines:

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[7] Jacob Darwin Hamblin, *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005), 22-25.

[8] Appel, *Shaping Biology*, 39, 38, 43. Appel provides a background of the funding environment from which the *Alpha Helix* and its fellows emerged, including NSF's ongoing efforts to support biology in general and to target biological oceanography in particular, but allocates only a brief mention to the ships themselves.

developmental, environmental, genetic, molecular, regulatory, systematic, and psychobiology.[9] These divisions were intended to resist disciplinary splintering, to facilitate interdisciplinary work, and to encourage scientists to think and work across traditional boundaries, but it sometimes made it difficult to decide where a given proposal should go.[10] Oceanographer John A. Knauss reported claims that "one's chance of gaining NSF support was dependent upon the guy in the mail room since it was his responsibility to decide on which desk to drop an oceanography proposal." Even if apocryphal, as Knauss preferred to believe, the story reflects scientists' understanding of, and perhaps frustration with, early NSF organization.[11] However, the evidence does not suggest oceanographers suffered under this arrangement. Indeed, recognizing the scarcity of other funding sources for biological oceanography, NSF specifically singled it out for support.[12] In 1959 NSF director Alan Waterman argued to the National Science Board that NSF should identify and develop critical areas of science; assistant director for BMS John T. Wilson pointed to biological oceanography as one of three.[13]

Waterman and Wilson made this push in the era of rapidly expanding funding that followed the unsettling success of the *Sputnik* launch as part of the Soviet Union's contribution to the 1957-1958 International Geophysical Year (IGY). Oceanographers

[9] According to John A. Knauss, NSF "has from the beginning been organized mostly along disciplinary lines." "The Emergence of NSF as a Supporter of Ocean Sciences in the United States," in *50 Years of Ocean Discovery: National Science Foundation, 1950-2000*, 3-8 (Washington, DC: Ocean Studies Board, National Research Council, National Academy Press, 2000), 5. That this was not the case, at least not for BMS, is made quite clear in Appel's administrative history of that division. In 1958 BMS added an eighth program—metabolic—which took parts from the two largest programs, molecular and regulatory biology. Appel, *Shaping Biology*, 71.

[10] Appel, *Shaping Biology*, 63-64.

[11] Knauss, "The Emergence of NSF as a Supporter of Ocean Sciences in the United States," 5 n 9.

[12] Richard T. Barber and Anna K. Hilting, "Achievements in Biological Oceanography." In *50 Years of Ocean Discovery: National Science Foundation, 1950-2000*, 11-21 (Washington, DC: Ocean Studies Board, National Research Council, National Academy Press, 2000), 12.

[13] The others were tropical botany, later expanded to tropical biology, and computers in life science research. Forestry was added in 1961. Appel, *Shaping Biology*, 186-187.

applied the pressure of Cold War competition to generate US enthusiasm after the Soviet Union announced plans to deploy seven oceanographic vessels, ranging in size from 1200 to 5000 tons. While Soviet oceanographic programs were known for their extravagance—and general scientific opinion in the US understood this to be a case of substituting quantity for quality—the projected effort appeared alarming in light of a US program which could boast no ships over 1000 tons. In fact the only ship in US inventory that had been purpose-designed for oceanography was WHOI's R/V *Atlantis*, a 140-foot steel ketch built in 1930 and widely regarded as obsolete.[14]

Oceanographers used the concern generated by their version of the "missile gap" to have a Technical Panel on Oceanography added to the national committee planning US IGY activities. The panel instituted a number of projects, most notably the Island Observatories Project, headed in the US by the Lamont Geological Observatory and SIO, which used tidal gauges around the world to gather data, hoping to improve scientists' understanding of the correlation between ocean circulation and changes in sea level.[15] Efforts at the poles were also increased, though these too tended towards the physical branches of oceanography. While this focus was perhaps understandable, given the overall effort's title, it still drew criticism from some biologists, who felt excluded and so began to consider similar international programs with a more biological focus.[16] At their broadest, these plans would lead to the International Biological Program in the late 1960s and early 1970s.[17]

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[14] Hamblin, *Oceanographers and the Cold War*, 71; 69. *Atlantis* was sold in 1964 to Argentina; Stewart B. Nelson, *Oceanographic Ships: Fore and Aft*, (Washington, DC: Office of the Oceanographer of the Navy, 1971), 104.

[15] Hamblin, *Oceanographers and the Cold War*, 72; 74.

[16] Appel, *Shaping Biology, 228.*

[17] For the IBP, see Elena Aronova, Karen S. Baker, and Naomi Oreskes, "Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to

Meanwhile, oceanographers were busy planning a large-scale, international project of their own, and it leaned heavily on the biological ocean sciences for its justification. Flush with IGY enthusiasm, oceanographers established an international committee to encourage the spirit of cooperation engendered, at least theoretically, by the IGY.[18] The committee's leaders conceived in 1958 of a major international investigation of the Indian Ocean. The International Indian Ocean Expedition (IIOE) soon outgrew its IGY template, becoming a multi-year event during which research ships from around the world would converge on the little-studied region and conduct scientific programs of their own design, though ostensibly coordinated by a central council. In addition to the major oceanographic players, all the countries bordering the Indian Ocean were invited to participate; the program would include training, establishment or reinforcement of local programs, and the possibility of developing knowledge to improve the utilization of the resources of the sea.

Perhaps predictably, problems with coordination between nations and within the subdisciplines of oceanography quickly surfaced. In the words of historian Jacob Hamblin, the overall program of the IIOE "did not require that scientists work together for a common purpose but instead established an international arrangement in which they did not have to work together at all."[19] This conundrum of coordination between countries,

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the Long Term Ecological Research (LTER) Network, 1957-Present," *Historical Studies in the Natural Sciences*, 2010, *40*, no. 2: 183-224.

[18] Hamblin, *Oceanographers and the Cold War*, 101-102. The committee was the Special Committee on Oceanic Research (SCOR); the "S" later changed from "Special" to "Scientific." Behrman, *Assault on the Largest Unknown: The International Indian Ocean Expedition, 1959-65* (Paris: UNESCO Press, 1981).

[19] Hamblin, *Oceanographers and the Cold War*, 113-115. Though Hamblin addresses the interdisciplinary squabbles surrounding the IIOE, which served as a catalyst for some of the biologists' efforts, he mentions the vessels involved only in passing. For an overview of the US role in the IIOE, focused on its procedures and results, see Behrman, *Assault on the Largest Unknown.* Behrman's account is journalistic and largely positive, as one might expect in a UNESCO publication.

complicated by Cold War rivalries, affected the data-sharing and thus the scientific usefulness of the expedition. Coordination amongst the oceanographers themselves, even within the US program alone, was no less fraught with contention. Many biologists complained that a program promoted on the basis of its benefits to resource management was now neglecting the very discipline that studied those resources. Journalist Daniel Behrman reported,

> Just as the United States Congress opens its sessions with a prayer, [the oceanographers] would begin their meetings with ringing pronouncements about the biological resources of the ocean and how research could lead to better exploitation if it were properly financed. But they did not take the biological oceanographer seriously. . . . The biological oceanographers tended to feel left out of the big money. [20]

Indeed, Lamont Geological Observatory director W. Maurice Ewing, a leader in planning the US program, "strongly cautioned against giving approval to many proposals for the IIOE that were not explicitly connected to physical oceanography, even if they would result in good science."[21] The tension came to a head when it came time to schedule ships for the expedition in a sparse research vessel environment where not much had changed from the lead-up to the IGY.

During the planning for the IGY, the National Academy of Sciences, at the request of the ONR, the Atomic Energy Commission, and the Fish and Wildlife Service, had created a Committee on Oceanography (NASCO) for "advisory purposes and for planning, coordinating, and directing oceanographic research across a broad range of disciplines."[22]

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[20] Behrman, *New World of the Oceans*, 7.

[21] Hamblin, *Oceanographers and the Cold War*, 131-2.

[22] Ibid, 72. An earlier NAS Committee on Oceanography formed in 1927 "to consider the share of the United States of America in a world wide program of Oceanographical Research, and report to the Academy." It dissolved in 1937, having completed its mission by overseeing the foundation of WHOI and the publication of reports on the status and needs of US and international oceanography; Weir, *Ocean in Common*, 41-46, 49-51, 95-96.

NSF would later join its sponsors.[23] Composed of prominent scientists, it was led by geochemist Harrison Brown, pointedly *not* an oceanographer, under the theory that that would preserve the appearance of objectivity when NASCO recommended spending increases. Brown's selection had the added benefit of preventing squabbling between the major oceanographic institutions over the chair.[24]

Diplomatic as that decision may have been, complaints still arose over the constitution of the committee. Many biologists complained about NASCO's makeup, alleging a bias towards physical oceanography and deep-ocean research. While there were two biologists on the committee as originally constituted, they were Milner Schaefer, a fisheries expert working at the Inter-American Tropical Tuna Commission (notably located in La Jolla, near SIO) and Gordon Riley, known for a mathematical approach to plankton ecology. In other words, missing was anyone to speak for marine biology, a broader spectrum of fisheries biologists, or even limnologists. To address these concerns, Princeton biologist Colin Pittendrigh was added to the panel before the first chapter of the report was issued, though it is unclear how much input he had. In mid-1960, after the release of the first few chapters but well before the entire report was out, the committee was expanded further by the addition of Per F. Scholander, the aforementioned SIO comparative physiologist, and Dixy Lee Ray, a marine invertebrate biologist and associate professor of zoology at the University of Washington.[25] As with Pittendrigh, the role

[23] National Research Council (U.S.), Committee on Oceanography, *Oceanography, 1960 to 1970* (Washington, DC: National Academy of Sciences, National Research Council, 1959-1962), chapter 1, "Introduction and Summary of Recommendations," 2. [Hereafter NASCO.]

[24] Hamblin, *Oceanographers and the Cold War*, 143.

[25] Appel, "Marine Biology/Biological Oceanography and the Federal Patron: The NSF Initiative in Biological Oceanography in the 1960s,"in *Oceanographic History: The Pacific and Beyond*, ed. Keith Rodney Benson and Philip F. Rehbock, 332-342 (Seattle: University of Washington Press, 2002): 333-4; Appel, *Shaping Biology*, 189. As a woman successfully working in a predominantly male field and the first woman to hold a prominent position at NSF, and as a marine biologist carving a successful career ashore, Ray

these two scientists played in NASCO's deliberations is unclear, but both would go on to play other key roles in defending biological oceanography's piece of the funding pie.

As expected, NASCO did recommend spending increases. Published between 1959 and 1962 in a series of twelve chapters, NASCO's *Oceanography, 1960-1970* laid out "the problems to be solved concerning the oceans," which, it claimed, were "at least as urgent as those of space."[26] It recommended doubling support for marine sciences over the ten-year period to come while increasing support for applied science and wide surveys. The report even suggested how to divide financial responsibility among funding agencies. "The cornerstone of our oceanographic endeavors" would remain "basic research," which would "require increases in both manpower and in facilities." The committee then tried to position oceanography alongside the "big science" physics programs of the post-Manhattan Project era: "Of particular importance among the facilities are ships, which are to the oceanographic what cyclotrons or reactors are to the nuclear physicist. He simply cannot undertake adequate research without them."[27]

Chapter Six of the report, published separately in 1959, tackled the specifics of these "New Research Ships," proposing their size, equipment, regulation, manning, and financing. In the immediate aftermath of World War II, as new university oceanography programs proliferated amid a sudden surplus of vessels, ship conversions had provided many new vessels quickly, but NASCO now recommended purpose-built ships to replace

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deserves more historical attention than she has yet received. She went on to head the Atomic Energy Commission and to be elected governor of the state of Washington. For one approach to her career, see Erik Ellis, "Dixy Lee Ray, Marine Biology, and the Public Understanding of Science in the United States (1930--1970)," Ph.D. diss., Oregon State University, 2006. Proquest (3206985).

[26] NASCO, ch 1, 3. A similar report sponsored by ONR in 1959, known as TENOC (Ten Years in Oceanography) also recommended broad expansion of government support for oceanography, though it focused more specifically on physical sciences seen as important for national security and was less widely publicized; see Hamblin, *Oceanographers and the Cold War*, 141-142.

[27] NASCO, ch 1, 5.

this aging fleet.[28] These newly built ships should fulfill four specific purposes: "Basic Oceanographic Research" at private labs, supported by government contracts; "Military Research and Development" at navy labs, manned mostly by navy crews; "Survey Ships," operated by the Naval Hydrographic Office, Coast and Geodetic Survey, and navy; and "Resources and Fisheries Ships," which would add the ability to catch fish on top of basic onboard laboratory requirements.[29]

While the requirement for resource and fisheries ships might suggest a recognized priority for biology—as with the IIOE program—the truth was that access to ships was an ongoing struggle between biologists and their colleagues in the physical ocean sciences. For one thing, the very wording of the proposal points to a shading of language often employed by physical oceanographers, one that no doubt had its roots in the interwar abundance of fisheries funding. Physical oceanographers tended, in true *Endless Frontier* fashion, to extol the importance of basic research in the seas, by which they almost always meant physical oceanography; when they referred to biological problems in the oceans, they resorted to the language of resources and fisheries.[30] These terms carried weight and assigned a higher relative scientific value to the supposedly basic physical science than to the allegedly applied biological. In the wake of the NASCO report's first chapters, a battle broke out between biological and physical oceanographers—some even saw a "schism."[31]

NSF's BMS, in the center of the melee, did its best to defend what they increasingly defined as the united field of biological oceanography, and many of their interventions

[28] NASCO, ch 6, "New Research Ships," 6.
[29] Ibid., 8-9.
[30] Vannevar Bush, *Science—The Endless Frontier: A Report to the President on a Program for Postwar Scientific Research* (Washington, DC: Office of Scientific Research and Development, 1945).
[31] Appel, *Shaping Biology*, 188.

involved ships. George Sprugel, program director for environmental biology at NSF, contacted key figures at WHOI to invite a proposal for a "ship-time" grant to answer the complaints of biologists; the result was a $22,500 grant for the purpose. BMS also inserted itself into the planning of WHOI's new research vessel—although it was being financed by NSF's Mathematical, Physical, and Engineering Science division—to make sure biology had a voice at the design table. And BMS had been key to Scholander's and Ray's addition to NASCO.[32]

BMS also hired Ray as a special consultant and chair of a new Ad Hoc Committee on Biological Oceanography. In this role, she travelled to marine laboratories around the country, interviewing scientists in an attempt to take the pulse of the field. Thus she was well aware, in the planning and early stages of the IIOE, that biological oceanographers were receiving short shrift in the scheduling of ship time. Physical oceanographers of course insisted that all scientific work could be done on the same ships. One of the strongest proponents of this viewpoint was Maurice Ewing, whose criticism of a proposal for a separate ship for meteorologists—in fact, he called it "silly"—suggested a certain disdain for the complainants.[33] At a NASCO planning meeting, Roger Revelle "complained that the biology program should not come out of 'Indian Ocean money,'" at which point Ray "remind[ed] the group that NASCO had long since endorsed the biology program as part of the expedition."[34] Incidents like these, on top of Ewing's active

[32] Ibid., 189.

[33] Ibid., 189; Hamblin, *Oceanographers and the Cold War*, 132.

[34] Dixy Lee Ray to [Harve J. Carlson,] Assistant Director for BMS, Memorandum: "Report on issues discussed at NASCO meeting that related to NSF interests," 22 January 1962, "Oceanography-General," Box 77, Office of the Director, General Records, 1949-63 (Dr. Waterman's Subject Files), Records of the National Science Foundation RG 307, National Archives, College Park, MD [hereafter, NACP].

advocacy for the rejection of non-physical proposals, left little doubt how biologists would fare on a shared ship.

Ray's Ad Hoc Committee reported in 1961 with a broad definition of oceanography, which did not narrow its focus to the deep sea or to its physical attributes alone. In fact, the concentration of biologists on the shoreline and shallow water, the committee felt, came in part because of their difficulty accessing the ships on which deep-water studies would depend. In response to first the NASCO and now their own Ad Hoc Committee's reports, NSF (and BMS within it) significantly increased funding for research ships. And of twelve large ships constructed or converted with NSF funds between 1958 and 1965, four would be specifically intended for biological oceanography.[35]

SHIPS FOR BIOLOGISTS

Ray addressed the most immediate need first, with the provision of ships for the IIOE biologists. She arranged funding for the conversion of a 243-foot long, 2085-ton vessel which had led several previous lives—as the private yacht *Aras* from 1931, the gunboat USS *Williamsburg* from 1941, and the presidential yacht of the same name for Harry Truman and, briefly, Dwight D. Eisenhower. Brought out of mothballs in 1962, it was converted by WHOI for IIOE research use as the R/V *Anton Bruun*, named after the prominent, and recently deceased, Danish marine biologist.[36] A second ship, the 135-foot, 336-ton, steel, two-masted auxiliary schooner *Te Vega*, was earmarked for use at

[35] Appel, *Shaping Biology*, 192.
[36] Nelson, *Oceanographic Ships*, 188.

Stanford University as a training vessel after its participation in the IIOE.[37] In all, BMS foresaw the involvement in IIOE "of 150 biologists representing approximately 100 different universities" in the US.[38]

The other two new BMS-funded additions to the oceanographic research fleet were intended to make ships available to support the regular and ongoing research programs of biologists, who "need[ed] and want[ed] the opportunity" to study "the off-shore areas of the ocean," as Duke University Marine Laboratory (DUML) ecologist Cazlyn G. Bookhout insisted. "They have not been able to obtain this type of training because there are too few oceanographic vessels," he explained, echoing Ray's Ad Hoc Committee report, "and those which do exist are used primarily to meet the demands of basic and practical research in physical, chemical and geological oceanography."[39] While these needs were urgent, they did not suffer the time pressure of participation in an ongoing international program, so the two new biological oceanography vessels would be designed and built to purpose.

Bookhout informed NSF in August 1960 that DUML—a small but ambitious program in Beaufort, NC, dating from the mid-1930s—would request funding "to build a vessel for oceanography and to initiate a cooperative research and training program in biological oceanography" for all the marine laboratories in the US, but especially those in the region, which lacked other facilities.[40] Bookhout and his team visited WHOI for advice on requirements and investigated—and rejected—surplus navy and coast guard

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[37] Ibid., 180.

[38] Federal Council for Science and Technology, Interagency Committee on Oceanography, *National Oceanographic Program, FY 1964.* ICO Pamphlet No. 11 (Washington , DC: Interagency Committee on Oceanography, 1963), 9. This report was also included as Appendix 6 to United States Congress, House of Representatives, Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries, Hearings, *National Oceanographic Program -- 1965: Hearings*, 88th Cong., 2d sess. (Washington, DC: Government Printing Office, 1964), 497-565.

[39] Cazlyn G. Bookhout, *The Origin and First Thirty-Five Years of Duke University Marine Laboratory* ([Durham, NC]: Duke University, 1992), 43.

[40] Bookhout, *Origin and First Thirty-Five Years,* 37.

hulls available for conversion. They drafted plans for an 84-foot "vessel for biological oceanography to operate primarily from Virginia to Florida and from the shoreline through the Gulf Stream to the outer edge of the continental shelf," along with support facilities, a shore laboratory, and funding for graduate students and lecturers.[41] Bookhout estimated eighty percent of the new ship's time would be used on research, with twenty percent available for training students.[42]

Dixy Lee Ray visited DUML in January to discuss the plans, and at the end of the month Bookhout submitted his formal proposal. Harve Carlson, who had headed BMS Facilities and Special Programs briefly before becoming deputy assistant director of BMS, visited in March, bringing with him physical oceanographers Athelstan Spilhaus and Fritz Kozcy. These latter two recommended a larger vessel; Bookhout and his team decided to revise the proposal accordingly. By June 1961 the grant had been approved.[43] After the usual long process of design, approval, and building, the finished vessel—117 feet 6 inches long and displacing 474 tons—was christened the R/V *Eastward* and delivered to the DUML pier to be equipped with its oceanographic gear in 1964.[44]

The second, and more ambitious, new-design proposal came from Per Scholander at SIO.

BIOLOGICAL OCEANOGRAPHY AT SCRIPPS

In the early 1950s, ichthyologist Carl Hubbs at SIO became concerned as director Roger Revelle steered the institution towards the suddenly more lucrative physical end of

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[41] Ibid., 45-6.
[42] Ibid., 42.
[43] Ibid., 49. On Carlson's career, see Appel, *Shaping Biology*, 157.
[44] Bookhout, *Origin and First Thirty-Five Years*, 50; Nelson, *Oceanographic Ships*, 187.

the oceanographic spectrum. Clearly understanding the financial realities involved, Hubbs suggested that "[a] more auspicious balance would result if major support could be obtained for biological work at Scripps."[45] An ensuing proposal to the Rockefeller Foundation resulted in a one million dollar grant in 1954 "for the development of a research program in marine biology" at SIO. [46] The Rockefeller funds provided—in addition to laboratory equipment, staff, graduate and post-graduate fellowships, a visiting professorship, and an international symposium on marine biology in 1956—four new professorships in the biological subdisciplines of ecology, microbial biochemistry, experimental phycology, and physiology. The last was filled by Per Scholander, who arrived in September 1958.

Writing to deputy assistant NSF director Louis Levin four months later, Scholander noted that the purpose of his appointment was "to build up facilities for pursuing research in marine physiology," and he would be "starting virtually from scratch, as far as local conditions were concerned." Among the specific needs he identified—including basics such as a secretary, technician, and "adequate space"—was laboratory equipment, both "standard" and "special seaborne equipment, such as respirometers, aquaria, and special supports for balances and optical equipment," and collecting equipment such as "a portable high-speed deep-sea winch," a "high pressured

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[45] As these comments are far less critical then Hubbs' previously-cited complaints about him, it should perhaps be noted that these were both made directly to Revelle and cited in an official biography of the Institution; Memorandum to Roger Revelle, 21 July 1953, quoted in Elizabeth Noble Shor, *Scripps Institution of Oceanography: Probing the Oceans, 1936 to 1976* (San Diego: Tofua Press, 1978), 202.

[46] Shor, *SIO*, 202. British zoologist C. M. Yonge, in a 1956 overview of marine biological laboratories, noted that little biological work had thus far been done at SIO, but that he hoped the Rockefeller grant would "help to correct the balance," "Development of Marine Biological Laboratories," *Science Progress* 44, no. 173 (January 1956): 7.

circulated aquarium for ship and lab use," and "Aqualung diving equipment." "Ship's Time and Other Transport Charges" also made his list.[47]

In 1959 SIO operated no fewer than five ships, of which four—the *Spencer F. Baird, Horizon, Orca,* and *Stranger,* ranging from 100 to 143 feet in length and 200 to 505 tons—were oceangoing and one, the 80-foot *Paolina-T*, was smaller and more suited to coastal work.[48] By the summer of 1959 Scholander ran a draft proposal past Dale Lindsay, Assistant Chief of Division Research Grants at the National Institutes of Health, "that one of the ships at Scripps Institution of Oceanography be equipped for experimental biological research." Yet the wording of this proposal suggests his real purpose was to control the ship, not just equip it; by the final paragraph, he foresaw that "When such a ship-borne laboratory has been created we shall have a national and we hope, also an international facility for pursuing [experimental] biological research on the sea." [49] Who controls a ship's schedule sets its research agenda, and equipment aside, the IIOE experience had demonstrated to biologists the difficulty of wresting it away from the physical oceanographers. Scholander wanted the ship, not just the equipment.

He identified three deterrents that kept experimental biologists ashore: "(1) United States has no oceanic vessel which is suitably equipped for experimental biological work; (2) biologists in general do not command sufficient funds to buy time on oceanographic vessels; (3) as a consequence of 1 and 2, most biological work on the sea is limited to collecting of material when best it can be fitted into a program sponsored by

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[47] Scholander to Levin, "Biological and Medical Facilities," 5 January 1959, "Funds Request," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 3, SIO Archives.

[48] NASCO, ch 6, 18, 20.

[49] The bracketed word was a hand-written addition to the original. Scholander, "Proposal for Experimental Biological Research from Ship-Borne Laboratory," June 1959, "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

physical oceanography."[50] While such collaboration might sometimes yield high quality science, an arrangement in which "whole areas of biological oceanography are welded to physical oceanography" had its limitations, for those thus reduced to dependency as well as for those left out because of their requirements for more specific equipment. After consulting "a dozen or so of the leading animal and plant physiologists in the country," Scholander decided that "[w]hat we need . . . is a ship-borne laboratory; that is an ocean-going vessel specifically equipped for experimental marine biology."[51] He began collecting from colleagues around the country both explanations of work they had done at sea and testimonials as to why they needed a dedicated vessel.[52]

The quickest and most obvious way to get a ship—not to mention the cheapest—would be conversion. In the wake of a global war, so much of which had occurred at sea, a proliferation of vessels was available for conversion to scientific purpose, as SIO's then-current fleet demonstrated. Both the *Spencer Baird* and *Horizon* started life as tugs; *Orca* had been a US Coast Guard vessel, as had a sister ship at WHOI; and *Stranger* began its life as a yacht. [53] Scholander pursued this possibility on two fronts.

First, he looked for a potential research vessel overseas. A native of Sweden, Scholander was raised and educated in Norway, and though he had since become an American citizen and spent many years in the US, his most recent academic position had

[50] P. F. Scholander, "Proposal to National Science Foundation for Ship-Borne Laboratory," April 1960, "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

[51] Ibid.

[52] For example, H. D. Johnson, Project Leader, Climatic Studies, University of Missouri College of Agriculture, to P. F. Scholander, SIO, 30 December 1959, and George A. Bartholomew, Chairman, Department of Zoölogy, University of California Los Angeles, to P. F. Scholander, SIO, La Jolla, 11 January 1960, both in "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

[53] Nelson, *Oceanographic Ships*, 131.

been at the University of Oslo. No doubt, then, he returned to the US inspired by Norway's new, 113-foot, 186-ton research vessel *Helland-Hanson*, completed in 1957, which had "the lines of a trawler with a high bow, ample open deck and roomy hull" and an onboard laboratory as well as berthing for seven or eight scientists. Construction started in 1960 on a second such ship, to be completed later that year.[54] He also contacted Johan T. Ruud, a whaling scientist at the University of Oslo's Biological Laboratory, who responded in February 1961:

> I can imagine that a seal-catcher will be suitable and also have the advantage that you could go to the Arctic and Antarctic. In Ålesund and Tromsø there are quite a few newly built seal-catchers made of steel, built for the New Foundland-catch. If Canada implements a 12 mile border—which we assume they will do soon—then I assume that many of these seal-catchers will become jobless. The boats are too large for Vesterisen, and the market for expedition vessels is, despite everything, limited. . . . I can even imagine that in the long run it will pay off to charter such a boat for some years, arrange it to suit your needs and run it with a Norwegian crew.[55]

A correspondent in Norway provided information on the pricing and lead time of having a research vessel built in Norway, which Scholander used as his guideline for initial proposals (and which led to later shock at the cost to build the eventual ship in the US).[56] An anonymous appraisal of the Norwegian design noted the lack of a radio room or

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[54] "European Scientific Notes," Office of Naval Research Branch Office, London, no. 14-2, 1 February 1960. "Misc. Lab Ship Correspondence" [a], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

[55] "Med hensyn til skip ken jeg tenke meg at en selfanger ville passé og ha den fordel at du også kenne gå til Arktis og Antarktis. I Ålesund of I Tromsø finnes endel bnybygde selfangere av stål, bygd for Newfoundlands-fangsten. Hvis Canada innfører 12 mils grense – hva vi anter de vil gjøre snart – anter jeg at mange av disse selfangerne blir arbeidsløse. Båtene er for store for Vesterisen, og markedet for ekspedisjons-fartåoyer er jo trots alt begrenset. . . . Jeg ken endog tenke meg at det i det lange løp ville lønne seg å charter en slik båt for noen år, innrede den for dine formål og kjøe denmed norsk mannskap." Johan T. Ruud to P. F. Scholander, 21 February 1961, "Misc. Lab Ship Correspondence" [a], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives. Translation by May-Lin Iversen.

[56] Translation of Sevrin Skjelten to P. F. Scholander, [translation probably by Scholander], "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [a], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

stowage for deck gear, crowded berthing areas, inadequacy of toilet facilities, and limited capacity for potable water. The US Coast Guard would also require modifications, such as a two-berth hospital and a second means of access/escape from each area of living quarters.[57]

Scholander also considered a mothballed US Navy ship, specifically a yard freighter (YF), which early in his search he believed "just about tailor-made to our purpose." [58] SIO's Marine Facilities Division ordered a "Preliminary Study on the Feasibility of Converting a U. S. Navy YF Self-Propelled Vessel into a Marine Biological Research Vessel," which San Francisco-based naval architects M. Rosenblatt & Son provided in January 1960.[59] In early March Scholander arranged to tour YF 885 at the Naval Ammunition Depot in Bangor, Washington, with SIO plant physiologist and chair of marine biology Francis Haxo and Captain Larry Davis, a ship's master from the Puget Sound Bridge and Drydock Company, along to provide expert opinions. The tour evidently went well, and Scholander discovered soon after that several of these vessels were laid up in San Diego. In April 1960 he submitted a proposal to NSF for conversion and operational funding; alongside it went a proposal to ONR asking for one of the 15 YFs mothballed in the San Diego Bay District's Reserve Fleet.[60]

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[57] "LABORATORY SHIP (Norwegian Design), General Comments on Review of Plan 1-17," "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [a], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

[58] P. F. Scholander, "Proposal to National Science Foundation for Ship-Borne Laboratory," April 1960, 6, "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

[59] M. Roseblatt & Son, Inc., Naval Architects & Marine Engineers, San Francisco, California, to Marine Facilities Division, SIO, La Jolla, January 1960, "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

[60] P. F. Scholander, "Proposal to Office of Naval Research for Loan of Yard Freighter (YF)," "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the

Despite the enthusiasm displayed in his correspondence, the YFs had certain shortcomings. Most worrisome was a rather short roll period in even light to moderate seas, which would, in Captain Davis's words, "be considered uncomfortable in a vessel required for general oceanographic work." But as Scholander expected most of the new ship's work to be done at anchor, Davis added, perhaps it "might be of less than the usual significance."[61] What is insignificant to a seasoned ship's master, however, might be quite uncomfortable for a biologist whom one is trying to lure out to sea. The naval architects conducting the feasibility study also noted the roll characteristic, which, while not a problem for stability, was "[f]or research purposes and comfort . . . a most undesirable feature." They recommended, "[f]or the intended use of the ship and consideration of comfort," adding weight to raise the center of gravity and increase the roll period, yet the additional weight would increase the vessel's draft "a little more than 2 feet." (Someone—likely Scholander—wrote in the report's margin, "undesirable.") Increasing the draft would decrease the freeboard, they also noted, and sufficient freeboard was "most desirable" for seaworthiness. In other words, the change would sacrifice seaworthiness for comfort; the handwritten memo summarized, "i.e., leave period alone!"[62]

Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives. This document is undated but filed with the April 1960 NSF proposal, and the wording of the two clearly suggest they were a package.

[61] Davis refers to "a sea condition of force 4" by which it is unclear if he means a 4 on the Beaufort wind force scale or the Douglas sea scale, but neither refers to particularly rough weather; Larry Davis, Master, M/S *Snatch*, Puget Sound Bridge & Drydock, to Per Scholander, 14 March 1960, "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives. A ship with a short roll period would roll side to side quickly instead of slowly, which would be uncomfortable but also make it difficult to hold anything steady.

[62] M. Rosenblatt & Son, Inc., Naval Architects & Marine Engineers, San Francisco, California, to Marine Facilities Division, SIO, La Jolla, January 1960, 5. "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives. Draft is the depth the ship extends downward into the water; increasing draft would limit the ship's ability to safely enter shallow water. Freeboard is the height from the waterline to the

Regardless, ONR informed Scholander in May 1960 "that getting a boat out of mothballs in a reactivated status would be most difficult and that an attempt to pick up a suitable craft as it is being retired would likely be more successful."[63] Perhaps this was just as well, for Scholander seems to have preferred the idea of a purpose-built vessel, designed from the keel up for the purposes of marine biology, though he still imagined it "an American counterpart of the Norwegian laboratory ship."[64] In fact, he explained in a February 1961 "Advance informal copy" of a proposal to both NSF and the National Institutes of Health (NIH), "The basic design is that of a modern standard Norwegian trawler, built for commercial operations in the North Atlantic. As such it is eminently seaworthy, relatively low in cost, and economical in operation." The ship would be

> of modest size, 123 feet long and 24 feet wide. It is powered by a 600 HP diesel engine which gives it an economical cruising speed of 11 knots, and it carries enough fuel for 65 days at this speed. The propeller is reversible from the bridge, which makes for easy handling and a continuous speed range from zero and up, which is a most important feature. The lab version of the standard ship will be thermally insulated and air conditioned for operations in the arctic as well as tropical waters. The bow will be reinforced for moderate ice work. [65]

As with the *Eastward*, the proposal included a laboratory, in this case the Physiological Research Laboratory, which included a large ring pool for marine mammal research and was designed to "form a bridge between physiologists at SIO and biologists at

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ship's main deck; decreasing freeboard would make thus make the ship sit lower in the water, and limit the sea state the ship could stand without water coming over the side.

[63] Loyal G. Goff, Physiology Branch, ONR, to P. F. Scholander, 3 May 1960; "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [b], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

[64] Scholander did not retain replies to these early proposals; NSF, at least, did not retain copies of proposals that did not become grants. P. F. Scholander to J. T. Spencer, Program Director for Special Programs, NSF, 20 December 1961, "Misc. Lab Ship Correspondence" [a], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

[65] P. F. Scholander, "Proposal to National Institutes of Health for Laboratory Ship and Related Home Base Facilities," February 1961, 6; "NIH-NSF, April 1961," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 3, SIO Archives.

the new School of Science and Engineering of UCSD and the medical school to be established at UCSD."[66]

NIH declined to support the project, but NSF was quite interested.[67] In August, J. T. Spencer, Program Director for Facilities and Special Programs, asked for a revised budget, but he warned Scholander that "there has been considerable discussion here in Washington in recent weeks about the problem of purchasing foreign built ships." Spencer promised to inform him if a final policy decision were made that would prevent the construction of a vessel in Scandinavia.[68] Scholander pushed compromise options, including the possibility of keeping the vessel Norwegian flagged, but expressed doubts about the NSF funding and began to consider other sources.[69] By October, a policy had indeed been enacted preventing the expenditure of NSF money on foreign–built ships.[70] Spencer asked Scholander to investigate the cost of building the vessel in the US and offered to proceed on the shore-based lab portion of the grant independently. By December a preliminary proposal was in the works, though the cost was expected to at least triple; by January 1962 it had in fact quadrupled.[71]

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[66] Shor, *SIO*, 168.

[67] Carl R. Brewer, Chief, Research Grants Branch, Division of General Medical Sciences, NIH, to P. F. Scholander, 21 August 1961; "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [b], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

[68] J. T. Spencer, Program Director for Facilities and Special Programs, NSF, to P. F. Scholander, 28 August 1961; "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [b], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

[69] Scholander to J. T. Spencer, Program Director for Facilities and Special Programs, NSF, 11 October 1961; "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [b], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

[70] J. T. Spencer, Program Director for Facilities and Special Programs, NSF, to Scholander, 18 October 1961; "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [b], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

[71] F. N. Speiss, Acting Director, SIO, to J. T. Spencer, NSF, 19 December 1961; F. N. Speiss to J. T. Spencer, 17 January 1962. "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October

Costs seem to have given NSF less pause than did their perception of the ship as aligned exclusively with Scholander's work. SIO assured Spencer in a strident seven-page letter signed by both Acting Director Fred Speiss and Chairman of the Division of Marine Biology Francis Haxo that the ship was intended to serve the entire body of biologists at Scripps, including plant physiologists, microbiologists, vertebrate biologists, biochemists, microbial biochemists, and experimental phycologists and twenty three graduate students in Haxo's division, as well as the scientists in the Division of Oceanography studying zooplankton and animal ecology and their associates and graduate students. Attached were pages of curricula vitarum and references.[72] Apparently mollified, NSF approved the grant in May and made it official at the end of June. [73]

A FLOATING BIOLOGICAL LABORATORY

The future *Alpha Helix*—so thoroughly associated with Scholander by this point that his colleagues at SIO jokingly referred to it as the "Schoboat"—was designed by Seattle naval architect L. R. Glosten, who had previously been responsible for the design of

1959-March 1969" [b], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

[72] F. N. Speiss, Acting Director, SIO, and F. T. Haxo, Chairman, Division of Marine Biology, SIO, to J. T. Spencer, NSF, 7 March 1962, "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [c], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives; the grant letter was Alan T. Waterman, Director, NSF, to Clark Kerr, President, University of California, Grant NSF G-24831, 30 June 1962, "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [c], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

[73] F. N. Speiss, Acting Director, SIO, to J. T. Spencer, NSF, 19 December 1961; F. N. Speiss to J. T. Spencer, 17 January 1962. "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [c], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives; the grant letter was Alan T. Waterman, Director, NSF, to Clark Kerr, President, University of California, Grant NSF G-24831, 30 June 1962, "NSF Laboratory Ship and Related Home Base Facilities, G-24831, October 1959-March 1969" [c], SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 14, SIO Archives.

SIO's unique Floating Instrument Platform, the *FLIP*.[74] After a bidding process in which only two bids were received—both of them higher than hoped—the ship was built at Martinac Shipbuilding Corporation of Tacoma. The ship expanded slightly en route, to 133 feet in length with a 31-foot beam, a 10.5-foot draft and 512 tons displacement. A veteran Arctic researcher who joked about dragging other scientists north in order to "infect" them with Arctic fever, Scholander had expansive views of the areas this ship would open to biology. It featured a carefully-designed, zoned air conditioning system for the tropics as well as a reinforced hull for light ice operations.[75]

The ship was consistently referred to as a "floating laboratory," and the laboratory facilities certainly took pride of place, comprising, as one observer described them, "two basic laboratories with an excellent array of analytical instrumentation, specimen holding facilities, etc., and ~~individual~~ benches [space] for about ten investigators."[76] On the main deck, three-quarters of the twenty-four by twenty-six-foot lab space was furnished as a main laboratory—elsewhere referred to as the chem lab—with a refrigerator and freezer, fume hood, and a liquid scintillation counter, as well as plentiful bench space and several sinks. Later the ship would provide a platform for the first shipboard use of an electron microscope; though this did not become standard equipment, it does emphasize the degree to which the laboratory could be equipped flexibly to meet individual missions.[77] The

[74] Shor, *SIO*, 170.

[75] Scholander, *Enjoying a Life in Science* (Fairbanks: University of Alaska Press, 1990), 42; "THE R/V ALPHA HELIX: A modern floating laboratory for experimental biology," 20 February 1967, "The RV Alpha Helix," SIO Alpha Helix Program Office Records, 1964-1980. (89-026), SIO Archives.

[76] Lloyd E. Slater to Tropical Biology Study Committee, "Memorandum," 16 January 1967, 2, "Folder 370, AH Functional Arrangement," Box 6, SIO Alpha Helix Program Office, November 1963-December 1967 (81-14), SIO Archives. Annotations handwritten in the original.

[77] No doubt cost played a part in the temporary nature of this use; the electron microscope was provided on loan by Carl Zeiss, Inc. The trial was successful as a feasibility study, and the R/V *Glomar Challenger* would later include an electron microscope as part of ship's equipment; National Advisory Board for the R/V *Alpha Helix, The Floating Biological Laboratory: Concept and Realization, An Assessment of*

remaining quarter of the facility on this deck was a wet lab—also referred to as the chill lab—which could be chilled to 5°C. Special, non-toxic pipes provided sea water to its water tables.[78]

One deck down—and a set of stairs (or ladder, in nautical terms) was conveniently placed in the main laboratory—lay a well-equipped "electrophysiological" laboratory. Sometimes referred to as a neurophysiology, physiology, or optical laboratory, this space was equipped with a sink, bench space, and, after its first expedition, a centrifuge. Here, too, equipment could be added as needed on later expeditions, such as the installation of a respiratory mass spectrometer for the 1970 Guadalupe Island, Mexico, expedition. [79] A small photo lab with dark room capabilities lay in the forward, starboard corner of the lab space. Beside this a large, walk-in freezer (Scholander on at least one occasion referred to it as "a small -20°C freeze laboratory") could hold samples until time was found to work on them or could transport samples back to a stateside lab.[80]

A large and well-equipped machine shop filled the port half of the lower lab space, complete with wood- and metal-working tools such as a grinder, lathe, oven, drill press, milling machine, air compressor, and welding equipment, with which equipment could be made, modified, or mended on scene. This was a feature Scholander had stressed as vital

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the First Five years of Operation of the Research Vessel Alpha Helix*, 1966-1970, and Recommendations for Its Future Mission*. Report requested by the National Science Foundation, May, 1971, 24.

[78] Scholander, "Proposal to the National Science Foundation: Support for Research Program for Physiological Laboratory Ship, R/V ALPHA HELIX," 24 May 1965, "Revised Budget to Proposal UCSD – 1546," 5, SIO Physiological Research Laboratory Office of the Director (Scholander) Records, 1963-1970, Box 3 (84-18), SIO Archives.

[79] National Advisory Board for the R/V *Alpha Helix, Floating Biological Laboratory*, 26.

[80] Though this could be problematic, when evaluating the extent to which the *Alpha Helix* truly operated as a laboratory; historian Joanna Radin reports an anthropological expedition in the early 1970s which gathered blood samples from Pacific Islanders, none of which were examined at sea and most of which remain unexamined today, "Life on Ice: Frozen Blood and Biological Variation in a Genomic Age, 1950-2010," Ph.D. diss., University of Pennsylvania, 2012, ProQuest (3509395); Scholander, "Proposal to the National Science Foundation: Support for Research Program for Physiological Laboratory Ship, R/V ALPHA HELIX," 24 May 1965, "Revised Budget to Proposal UCSD – 1546," 5, SIO Physiological Research Laboratory Office of the Director (Scholander) Records, 1963-1970, Box 3 (84-18), SIO Archives.

from his earliest conceptions, as he had a long history of improvising equipment as the need developed. Though not explicitly recognized, this also followed a pattern set by *Challenger* and other earlier expeditions, when naturalists aboard government-owned vessels worked with ships' blacksmiths to modify or create equipment to meet their needs in the field.[81]

The ship had "an exceptionally large fantail (much more spacious than ships twice her size)" as one observer reported, allowing ample room for collecting and experimentation on deck.[82] A generous hold for scientific storage, with covered access from the fantail, also held a jeep, a dismantled prefabricated shore laboratory, and two or three small skiffs.[83] A light trawl winch carrying 15,000 feet of 3/16-inch-diameter wire, a main hydrographic winch carrying 3/8-inch-diameter cable "capable of trawling with a small net down to 1,000 meters down," and a five-ton-capacity cargo crane were mounted on the upper deck, along with the work boat, a 24-foot cabin cruiser.[84] "The ship's propulsion system," Scholander remembered later, "incorporated special features to improve its ice-going capability, including a single deepseated reversible,

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[81] See chapter 2, above. Other examples include the "deep-sea Clamm," a "clever contraption" for sampling the deep sea floor created by the ship's blacksmith during Sir John Ross's 1818 expedition to Baffin Bay; cited in Schlee, *Edge of an Unfamiliar World*, 85. Helen M. Rozwadowski has examined this tradition in "'Simple Enough to be Carried out Onboard': The Maritime Environment and Technological Innovation in the Nineteenth Century," in Svante Lindqvist, Marika Hedin, Ulf Larsson, eds., *Teknikens landskap: en teknikhistorisk antologi tillägnad Svante Lindqvist* ([Stockholm]: Atlantis, 1998): 83-98.

[82] The fantail is the open deck area at the stern of the ship. Lloyd E. Slater to Tropical Biology Study Committee, "Memorandum," 16 January 1967, 2, "Folder 370, AH Functional Arrangement," Box 6, SIO Alpha Helix Program Office, November 1963-December 1967 (81-14), SIO Archives; "THE R/V ALPHA HELIX: A modern floating laboratory for experimental biology," 20 February 1967, 2, "The RV Alpha Helix," SIO Alpha Helix Program Office Records, 1964-1980 (89-026), SIO Archives.

[83] Scholander, "Proposal to the National Science Foundation: Support for Research Program for Physiological Laboratory Ship, R/V ALPHA HELIX," 24 May 1965, "Revised Budget to Proposal UCSD – 1546," 5, SIO Physiological Research Laboratory Office of the Director (Scholander) Records, 1963-1970, Box 3 (84-18), SIO Archives.

[84] Ibid.

controllable-pitch propeller, protected by rugged ice fins, which were to prove their worth at a later date."[85]

Yet for all of the boosterism surrounding the "floating laboratory" concept, what seemed most important to Scholander and his colleagues was how imperceptible they could make the floating. Modern physiology often required the study of organisms *in situ*, whether large, live animals or plants that would be impossible to transport or samples and components whose chemistry or structure might not survive transportation or freezing intact.[86] Certainly the ship functioned as a field laboratory, providing the opportunity to combine field and lab practice in a novel and theoretically useful way, by transporting the laboratory into or close to the field environment while maintaining the exacting standards of calibration, climate-controlled storage, and equipment availability of a nicely-equipped, traditional, shore-based laboratory—not to mention the modern toilet and shower facilities, fully-equipped galley, "automatic laundry," and air conditioning that a field lab might frequently lack.

But when one observer explained the ship's capabilities in the context of a possible future tropical biology lab, emphasizing the "analytical instrumentation" and "electronic gear," someone, likely Scholander, amended his report, "All labs have flat horizontal floors." [87] It is not just a landlubber speaking when the term *floor* is chosen over deck; the intention here—and elsewhere, as this feature received recurring emphasis—seems to stress the degree to which the shipboard lab was *not* ship-like.

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[85] Scholander, *Enjoying a Life*, 147.

[86] Lloyd E. Slater to Tropical Biology Study Committee, "Memorandum," 16 January 1967, 4, "Folder 370, AH Functional Arrangement," Box 6, SIO Alpha Helix Program Office, November 1963-December 1967 (81-14), SIO Archives

[87] Ibid.

A level platform would be important for certain experiments, but however horizontal one's floor, it will rarely stay that way in even the lightest of seas. And indeed, from its earliest conception, Scholander had clearly intended the ship to move the lab to the biologists' traditional field station, not necessarily to do work in the deep oceans, where most physical oceanography took place. Early evaluation of the suitability of converting a YF, above, referenced Scholander's expressed desire to do most work at anchor or ashore as perhaps mitigating the impact of the vessel's unfortunate roll characteristics. During the bidder's conference before construction of *Alpha Helix*, Scholander "stated that about 90% of the laboratory work will be performed while the ship is in anchored position in order to reduce the effect of motion on the instruments and the scientific personnel."[88] Future *Alpha Helix* captain James Faughn, SIO's on-site representative during the vessel's construction, expressed similar expectations for the small work boat the ship would carry; it should be "as large and roomy as can be handled" from the ship, which should be facilitated by the fact that it will not be "designed with a view (except on rare occasion) to being handled on and off the vessel in the open sea." The work boat itself should have "limited open sea capability."[89]

Beyond simply working at anchor, *Alpha Helix* was equipped to provide stable electrical power to a nearby shore station. Much of the first scientific program on its inaugural expedition, for which Scholander was chief scientist, "was spent ashore

[88] "UCSD BIDDER'S CONFERENCE OF MAY 6, 1964," "Bid Documents, 1964-1965," SIO Alpha Helix Program Office Records, 1964-1980. (89-026), SIO Archives.

[89] James Faughn, "Notes on Work Boat," [no date; probably September or October 1965], 1. "ALPHA HELIX; Bid Documents, 1964-1966," SIO Alpha Helix Program Office Records, 1964-1980. (89-026), SIO Archives.

operating out of a sand spit field laboratory which was supplied from the ship."[90]

Scholander later confirmed,

> It was part of the original plan to build a shore camp with a dining tent and sleeping tents for another dozen people. . . .
>
> The shore camp was set up on a sandy beach, with the Alpha Helix anchored nearby. A cable from her supplied power for light and instrumentation. I, for one, did all my osmotic work ashore in a small prefabricated lab, used on previous expeditions, the only place where it was possible to use the Mettler balance.[91]

Chronological proximity to the ship's origin and personal supervision by Scholander suggest this first expedition will have followed the original intent most faithfully. Examining it can serve as an example of how the shore-ship division of labor played out in practice. Between April and November 1966, the "Billabong" Expedition to the southeast coast of Australia and the Great Barrier Reef consisted of four major programs (A through D) involving thirty-one senior scientists and ten graduate students from thirteen institutions in the US, Australia, and Japan. While each of these programs was carried out by a core group of between two and six scientists, they were joined by a number of visiting scientists, since the shore lab provided the opportunity to expand the scientific party beyond the ship's capacity; in particular this allowed a number of Australian scientists to participate.[92] While this feature was perhaps mostly a convenience or collegial courtesy in Australia, Scholander foresaw it performing an important function when future expeditions took the ship to the environment of nations lacking their own scientific infrastructures. An overview of the expedition written before

[90] Lloyd E. Slater to Tropical Marine Biology Study Committee, "Memorandum," 16 January 1967, 4, "Folder 370, AH Functional Arrangement," Box 6, SIO Alpha Helix Program Office, November 1963-December 1967 (81-14), SIO Archives.

[91] Scholander, *Enjoying a Life*, 147.

[92] Slater to Tropical Marine Biology Study Committee, "Memorandum," 16 January 1967, 4, 6, "Folder 370, AH Functional Arrangement," Box 6, SIO Alpha Helix Program Office, November 1963-December 1967 (81-14), SIO Archives.

its departure affirmed, "The R/V ALPHA HELIX will essentially remain at anchor during this period at Princess Charlotte Bay, Queensland between Flinders and Stanley Islands, 14°11 minutes south, 144°, 13 minutes east."[93]

While much of programs A and D were "spent ashore operating out of a sand spit laboratory which was supplied from the ship," the shipboard laboratories also saw use from the beginning. Program A, led by Scholander, focused on "Fundamental Studies of Mangrove Physiology." Scholander's own work examined "the nature of reverse osmosis and salt secretion in the mangrove" and required the shipboard facilities for the "determinations of membrane freezing points" and to examine phosphate metabolism in various mangrove species through two-dimensional radio chromatography. Program D, led by Harold T. Hammel, concentrated on "Regulatory Physiology in Reptiles and Dugong" (though Hammel himself continued to work on mangroves, as well). Using aboriginal hunting methods, "after some unsuccessful attempts and miscellaneous adventures" the scientists managed to capture "four adult live dugong," ranging in weight from 250 to 480 kilograms, which were corralled in a floating pen moored near the shore camp and "forcibly dived" while fitted with electrocardiogram equipment.[94] The experiments on reptiles likely involved similar corralling, though some—specifically the study of their physiological response to varying temperatures—were probably carried out onboard ship.

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[93] Alpha Helix Australian (Billabong) Expedition, "R/V ALPHA HELIX Australian (Billabong) Expedition, April-October 1966: A Cooperative Scientific Program with Participants from Universities and Institutions of the United States of America and Australia." (La Jolla: National Science Foundation and Scripps Instituion of Oceanography, 1966), 1.

[94] Experiments requiring restraint were carried out by "wrapping in wet sheets and lashing to a plywood board." Robert Elsner, "Preliminary Report on Dugong Studies, August-September, 1966," in *Alpha Helix* Australian (Billabong) Expedition, 120.

Programs B and C, on the other hand, took place largely on the Great Barrier Reef itself and thus relied upon the ship's facilities. Led by T. H. Bullock, Program B studied "Neurophysiology of Reef Organisms." Specimens of reef fauna were collected daily by aboriginal hunters and analyzed "mainly within the precincts of the excellent neurophysiology laboratory aboard the HELIX."[95] Bullock made extensive use of the ship's photo lab, small boat, and SCUBA gear, while D. Hafemann and J. Hubbard made use of the ship's deck to time the running speed and film the movement of two species of crab.[96] Francis Haxo led Program C, which looked at "Physiology and Biochemistry of Symbiotic Associations." Kazuo Shibata tested a new recording spectrophotometer onboard, allowing him "to observe translucent and opaque samples as well as transparent solutions."[97]

Perhaps the most notable feature of the scientists' initial reports, provided at the end of their expeditionary work, is the widespread lack of distinction between the shore and shipboard laboratories. With the exception of actions performed *in situ* and occasional bouts of dugong wrestling, one cannot tell, reading the scientists' reports, where they performed most of the work. Unless some specific item or environment was lacking—which happened, but apparently rarely—they seem to have considered the two spaces equivalent in terms of the value they invested in them as "laboratories." In this sense, *Alpha Helix* seems to have achieved Thomas Gieryn's conception of the lab as a

[95] Lloyd E. Slater to Tropical Marine Biology Study Committee, "Memorandum," 16 January 1967, 4, "Folder 370, AH Functional Arrangement," Box 6, SIO *Alpha Helix* Program Office, November 1963-December 1967 (81-14), SIO Archives, 5.
[96] *Alpha Helix* Australian (Billabong) Expedition, 66.
[97] Ibid., 117.

"truth spot," which would "provide a stable core of placelessness even when enveloped by the field."[98]

Lawrence R. Blinks, studying giant algal cells as a part of Program C, called it "the best scientific expedition he was ever on." While this was largely due to "the unique combination of a good supply of rare organisms and the immediate accessibility of a first rate analytical laboratory," he also recognized "the remarkable unity of interest among the scientists, which led to continuous group interaction and continuity between the research projects."[99] To Blinks this appeared to be felicitous serendipity, but Scholander had counted on it from the beginning.

BEYOND THE LABORATORY

Whether its facilities are conceived as a floating laboratory or mobile field station or giant refrigeration unit, the ship performed at least two other vital—if perhaps more symbolic—functions for biologists, at least the first of which Scholander explicitly recognized and Blinks enjoyed. In proposing the ship, Scholander noted that "[o]n expeditions senior and junior scientists work together and can, without distraction, fully concentrate on their work. This togetherness breeds discussions and ideas . . ."[100] To facilitate this brainstorming, the ship's library and common spaces received Scholander's special attention during the ship's design and were stressed as important assets in summaries of the project. Already during construction, the aesthetics of the library

[98] Gieryn, "Three Truth-Spots." *Journal of the History of the Behavioral* Sciences 2002, *38*, no. 2: 113–132; cited in Radin, "Life on Ice," 179.

[99] Lloyd E. Slater to Tropical Marine Biology Study Committee, "Memorandum," 16 January 1967, 4, "Folder 370, AH Functional Arrangement," Box 6, SIO *Alpha Helix* Program Office, November 1963-December 1967 (81-14), SIO Archives, 5.

[100] P. F. Scholander, "Proposal to National Science Foundation for Ship-Borne Laboratory," April 1960, 4. "Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962," SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

garnered attention not lavished elsewhere, with a specification for "[r]andom width teak faced birch ply wood" paneling and for carpeting.[101] Neither wood paneling nor carpeting is the most practical of options for the marine environment, but both would assist in the creation of a place where "senior and junior scientists from various universities and disciplines [would come] to tackle problems together, undisturbed by the daily chores of the home base," a process Scholander identified as "[o]ne of the great assets of the ship. . . Such constellations of people are becoming increasingly difficult to realize."[102] Zoologist M. S. Gordon, chief scientist on a 1970 expedition, reported, "At three day intervals throughout the working period the scientific party gathered in the ship's library for extended seminar discussions of the work of various members. Eight such discussions were held, to the mutual interest and benefit of all concerned."[103]

This gathering and exchange process extended beyond the symbolic space of the library. As with the machine shop, Scholander's priorities here also had historical precedent, in this case going back at least as far as the *Challenger* expedition in the 1870s, during which Lieutenant Thomas Henry Tizard noted that "the after-dinner smoking circle provided the forum for officers and scientists to compare results and discuss their latest ideas."[104] The shore camp of the first *Alpha Helix* expedition, where Scholander reported,

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[101] James L. Faughn, handwritten note, no date, "ALPHA HELIX; Bid Documents, 1964-1965," SIO Alpha Helix Program Office Records, 1964-1980 (89-026), SIO Archives.

[102] "New Facilities for Experimental Biology at Scripps Institution of Oceanograophy," [no date], 3. "Alpha Helix Advisory Board," Scripps Institution of Oceanography Physiology Research Laboratory Office of the Director (Scholander) Records, 1963-1970, Box 3 (84-18), SIO Archives.

[103] National Advisory Board for the R/V *Alpha Helix, The Floating Biological Laboratory: Concept and Realization, An Assessment of the First Five Years of Operation of the Research Vessel* Alpha Helix*, 1966-1970, and Recommendations for Its Future Mission*. Report requested by the National Science Foundation, May 1971, 23.

[104] Cited in Margaret Deacon, *Scientists and the Sea, 1650-1900: A Study of Marine Science*, 2d ed. (Brookfield, VT: Ashgate, 1997), 337.

"After dinner we frequently had interdisciplinary lectures presented in the dining tent, which had a splendid blackboard," provided an almost exact parallel.[105]

These after-dinner lectures, eminent though the speakers may have been, were decidedly informal—Scholander reported the scientists adopting a pet bat who would roost at the top of the board and urinate on the chalk scribbles of any lecturer who proved boring—but more formal instruction took place on the expeditions as well. Biological oceanographer William Newman proposed that the transit "from the Great Barrier Reef to San Diego" at the end of the first expedition, "would provide a unique opportunity for offering a course on the ecology and environment of oceanic islands" for "carefully selected" graduate students. This would take advantage of the expeditionary nature of the ship as well as the unusual "constellation" of expertise, for "[c]omparable, broad experiences cannot be obtained by working in one place . . . for as nearly all tropical reef biologists and geologists have said, no two islands are the same, and this is true also for the diversity of environments associated with them."[106]

Beyond education and brainstorming, the formation of "constellations of people" in scientific settings is fundamental to the conception and cohesion of a discipline. When biologist Lloyd Slater reported "a small but splendid ship's library" and someone—probably Scholander—crossed through library and wrote to the side "library-conference room," this was less delusions of grandeur than expression of

105 Scholander, *Enjoying a Life*, 149.

106 William Newman, Department of Oceanography, SIO, to T. M. Bullock, "MEMORANDUM: Proposal for a course to be given during the return voyage of the ALPHA HELIX," 13 July 1966, "Correspondence, Alpha Helix, July-December 1966", SIO Alpha Helix Program Office Records, 1964-1980. (89-026), SIO Archives.

purpose.[107] The library was well-equipped, but its true function was to collect the expedition volumes, in which the scientific papers produced from each expedition would be bound together, validation of its mission and tangible evidence of the similar binding of scientists Scholander hoped to achieve.[108] Together, the ship "furnishes a 'magnet' for attracting and bringing together a critical mass of leading scientists . . ."[109]

The ship's second contribution to discipline formation was perhaps its least explicit but most fundamental. It is inherent in William Newman's course proposal, where, after enumerating the benefits of a shipboard course, he wrote, "Granted we cannot offer in a quarter's work what Darwin experienced on the voyage of the BEAGLE, but we can in good part provide the impetus and intellectual stimulation that will encourage students tol [sic] take a critical look at the tropics, where the greatest diversity on earth occurs and a comparable diversity of exciting research opportunities exist."[110] In the comparison to Darwin's historic *Beagle* voyage, Newman invoked the same scientific folklore as his predecessors on *Meteor* and *Challenger* had, portraying expeditionary science as exploration and heroic adventure. Modern historians have perpetuated this trope, as when Joanna Radin noted that for the biologists on *Alpha Helix*, "Like centuries of nautical explorers before them, this ship was a means of accessing regions seen as particularly

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[107] Lloyd E. Slater to Tropical Marine Biology Study Committee, "Memorandum," 16 January 1967, 3, "Folder 370, AH Functional Arrangement," Box 6, SIO Alpha Helix Program Office, November 1963-December 1967 (81-14), SIO Archives.

[108] "THE R/V ALPHA HELIX: A modern floating laboratory for experimental biology," 20 February 1967, 6, "The RV Alpha Helix," SIO Alpha Helix Program Office Records, 1964-1980. (89-026), SIO Archives.

[109] Lloyd E. Slater to Tropical Biology Study Committee, "Memorandum," 16 January 1967, 10, "Folder 370, AH Functional Arrangement," Box 6, SIO Alpha Helix Program Office, November 1963-December 1967 (81-14), SIO Archives.

[110] William Newman, Department of Oceanography, SIO, to T. M. Bullock, "MEMORANDUM: Proposal for a course to be given during the return voyage of the ALPHA HELIX," 13 July 1966, "Correspondence, Alpha Helix, July-December 1966", SIO Alpha Helix Program Office Records, 1964-1980. (89-026), SIO Archives.

remote from centers of calculation, including the Amazon and the islands of Melanesia."[111] That it was a means of accessing remote regions is inarguable; that it placed its scientists in the company of centuries of explorers is more loaded.

Oceanographers and their observers certainly viewed—and often still view—themselves and their work in heroic terms, as the titles and subtitles of their memoirs and biographies attest. Edward S. Barr's *The Venturesome Voyages of Scripps into the South Pacific Ocean, 1950 and 1952* (1975); Daniel Behrman's *Assault on the Largest Unknown: The International Indian Ocean Expedition, 1959-1962*; and *One Man's Noise, Stories of an Adventuresome Oceanographer*, a 1993 film biography of geophysicist Walter Munk, are just a few examples. Scholander's autobiography makes but brief mention of his scientific work but tells with relish stories of plane crashes, alligator wrangling, hands-on testing of emergency life-rafts off the Aleutian Islands, and parachuting onto a glacier to rescue a downed air crew (for which he was awarded a medal by the US Army), with frequent reference to Vikings and even Valhalla.[112]

Even a more sober examination of his curriculum vitae finds extensive expeditionary experience, beginning with botanical expeditions to Greenland while he was still in medical school. While on the faculty of the University of Oslo, he organized expeditions to Australia and extreme southern Chile to test the physiological adaptations of native peoples to cold environments, and he examined gas bubbles in glacier ice in Norway and Greenland before joining SIO. Scholander's ship proposal to NSF acknowledged "an element of adventure in expeditionary work which strongly appeals to many people. This

[111] Radin, "Life on Ice," 171.
[112] Scholander, *Enjoying a Life*, *passim*.

‘explorer’ drive is a valuable asset indeed, but it can be fully exploited only in a setting of adequate research facilities.”[113]

Historian Naomi Oreskes has broached the importance of this concept of heroic science in the context of gender roles in science. While observers frequently pointed to women’s supposed lack of objectivity as a reason for the limits on their scientific careers, Oreskes argues the limits actually followed from their exclusion from the forms of scientific endeavor seen as “heroic”—in her case study, a submarine expedition to measure the earth’s magnetism.[114] That the case for building the *Alpha Helix* did not explicitly involve the inclusion or exclusion of women makes it no less an example of the trope Oreskes has identified.[115] *Alpha Helix* was in no small part an assertion on the part of Scholander and his fellow biologists that they, too, were heroic, even masculine, and thus full-fledged members of the scientific community of oceanographers.

CONCLUSION

Along with the *Te Vega*, the *Anton Bruun*, and especially the *Eastward*, the research vessel *Alpha Helix* both facilitated and symbolized the growing power and coherence of biologists in the marine sciences. This process achieved its peak in 1968 when biological oceanography became its own program at NSF, thanks in no small part to

[113] Scholander, “Proposal to National Science Foundation for Ship-Borne Laboratory,” April 1960, 5, “Ship-Borne Lab, Proposal, 1960 NIH-NSF 1961-1962,” SIO Physical Research Laboratory Office of the Director (Scholander) Records, 1963-1970 (84-18), Box 2, SIO Archives.

[114] Naomi Oreskes, “Objectivity or Heroism? On the Invisibility of Women in Science,” *Osiris*, 1996, 2nd Series, *11*, *Science in the Field*: 87-113.

[115] Though SIO had no less complicated a history when it came to women in science, as attested by a 1949 memo from then-associate director Roger Revelle advocating the exclusion of women from SIO research vessels via “an unwritten policy which does not prohibit but subtly discourages their presence”; Revelle to Carl Eckart, “MEMORANDUM: Visitors on Ships of the Scripps Institution,” 20 April 1949. “Folder 20, Correspondence, March-April 1949,” S.I.O Office of the Director (Revelle) Records, 1930-1961, Box 1 of 23 (AC16), SIO Archives.

the people working at and with the funding agency to empower biologists to set their own agendas in the field.[116] Yet the funding that kept these ships going was fickle; in July 1968, President Johnson amended NSF's charter, putting an end to their broad definition of basic science and adding applied science to their fundamental mission. Between the bureaucratic desire for control and the budget realities of the Vietnam era, the NSF budget flatlined. Soon after, the 1969 Mansfield Amendment to the Defense Appropriations Act limited Defense Department spending on "research not directly relevant to its mission," significantly curtailing the support provided by ONR and other agencies. Physical scientists flocked to NSF for succor, in renewed competition for an already restricted budget.[117]

At the end of the decade, as the funding cuts began to be felt, NSF ordered the *Alpha Helix*, once hailed as ground-breaking for its biology-oriented configuration, to be retrofitted with an A-frame and winch. This heavy-lifting crane, which could be used to place large equipment packages such as weighted moorings that would secure instruments on several-mile-long lines in the deep ocean, were tools of physical oceanography. Henceforth the ship's time would be split across a broader spectrum of oceanographic subdisciplines.

Accounts of the first expedition demonstrate a fairly even split between shipboard and shore-based scientific work. Summary accounts of later expeditions suggest similar divisions, such as recounting shore observations and trawling operations as parts of the same program. Whether in line with the ship's original conception or not, the argument that the shore-based work could have been better completed by a traditional field camp

[116] Appel, *Shaping Biology*, 281;233.
[117] Ibid., 235; 233; 237.

would be one concern that led the NSF, as funding fell, to request the ship's national advisory board conduct an assessment of the ship's first five years of operation in 1971. This study determined that the ship was in fact the least expensive per scientific berth per day at sea of any in the SIO fleet, though this did not, of course, directly address the shore camp argument. A comparison of average cost per scientific publication produced also yielded evidence of the *Alpha Helix* providing a good deal as compared to "ordinary project grant experience."[118] The board also gathered the evaluations of the scientists who had participated in expeditions through 1970 for inclusion in the report. They testified "with astonishing agreement that the ALPHA HELIX is a very well designed instrument as a floating laboratory for the purposes originally set out."[119]

Perhaps this is to be expected in a report from a group quite interested in justifying the ship's continued operation. But the very enthusiasm with which the board—twelve scientists with sufficient eminence in the fields associated with biological oceanography that they had been selected to oversee the evaluation of research proposals for the ship's use—defended the ship's special nature recalls Scholander's more symbolic intentions for the ship. They pointed to the importance of the group dynamic onboard and to the special role that the expedition experience played in the careers of respondents—sending them down new lines of research, providing exposure to new methods and approaches—all things that could not have happened without Scholander's "constellation of people." It provided as well the "powerful . . . impact of the field and raw nature on a breed of indoor biologists who are seemingly permanently broadened by the vivid experience."[120] They

[118] National Advisory Board for the R/V *Alpha Helix*, *Floating Biological Laboratory*, 9; 13.
[119] National Advisory Board for the R/V *Alpha Helix*, *Floating Biological Laboratory*, 19.
[120] Ibid., 25.

argued the vital importance of maintaining the ship as an exclusive tool of biological oceanography.

The biologists' failure to maintain their control of the ship and its mission does not lessen the degree to which that control mattered, nor its symbolic purpose. On the contrary, that the ship could muster the kind of support it did in an effort to keep that environment not only available and accessible, but firmly in the hands of the discipline, argues for its value as a symbol. It had, in the course of five years, largely fulfilled Scholander's vision of the ship as a social and disciplinary tool, a focal point for collegial interchange and networking, and it had helped to build biological oceanographers into a recognized and recognizable community. They were no longer "a breed of indoor biologists." They had indeed been "permanently broadened by the vivid experience."

By 1972, NSF took responsibility for programming its block-grant-funded research cruises away from the national advisory board and began vetting each individual program separately. Ship operations were no longer in the hands of SIO, but instead controlled by the newly-formed University National Oceanographic Laboratory System.[121] The ship would lose all support by 1980, when it was sold to the University of Alaska-Fairbanks, to be operated by that institution's Seward Marine Center until its retirement and sale in 1996.

Today, *Alpha Helix* remains for sale at Stabbert Shipyard in Seattle, which "specializes in converting former government research and commercial ships into elegant, seaworthy exploration yachts."[122] For the right price, you can have your own

[121] Appel, *Shaping Biology*, 243.
[122] Second Hand Yachts, "133ft Martin STABBERT Expedition For Sale," accessed 16 October 2016, online at http://www.secondhandyachts.com/boats-for-sale/power-boats/133ft-martin-stabbert-expedition-other-1016.html

“versatile survey and scientific platform . . . able to access shallow water locations for scientific and survey work.”[123] For significantly more, you can have an elegantly-appointed yacht “designed for adventure travel in exotic and remote locations. [It] will deliver you, your family, and privileged guests safely to stunning destinations where natural beauty and fascinating culture are often unreachable by any other means.”[124] It would seem that scientists are not alone in placing a premium on adventure.

[123] This option no longer appears to be available, but was posted on Second Hand Yachts, “133ft Martin STABBERT Expedition For Sale,” [no date], accessed 07 December 2013, online at http://www.secondhandyachts.com/index.php?option=com_boatforsales&view=boatfor sale&catid=2:motoryacht&id=1013:133ft-martin-stabbert-expedition

[124] Converted, the listed price is currently $7.5 million, Second Hand Yachts, "133ft Martin STABBERT Expedition For Sale," accessed 16 October 2016, online at http://www.secondhandyachts.com/boats-for-sale/power-boats/133ft-martin-stabbert-expedition-other-1016.html

CONCLUSION

These studies demonstrate the importance of technologies in creating the scientific ocean, in making it a place for science and making science an appropriate tool for studying it over the course of the nineteenth and twentieth centuries. They demonstrate, too, that ships have always meant more than their scientific function, serving political purposes on the individual, organizational, disciplinary, national, and international levels. Ocean science practitioners had already taken the sounding lead, the dredge, the net, and other technologies from their predecessors on the sea and made them into technologies of science. Now they took ships—whether yachts or gunships or survey vessels—and adapted them into something new. And as the tools acquired more precise names as they were modified to better suit their new, scientific purposes, so too did the ship become a new thing, a research vessel.

In the process, researchers forged a new science, first coming together around an omnidisciplinary focus on the ocean as a place to do science. This place—the oceans—united naturalists and chemists, those interested in zoology and geology, as oceanographers, who defined their field as the global ocean and their career path as one that involved science on ships. Then, as those disciplinary lines grew strong enough to gain attention not just from fellow scientists from governments and navies and the public, they began to bind. By the Cold War, then, ocean scientists began to rediversify, relying on that established model of shipboard science to stake new claims to disciplinary importance, as did the biologists who designed, funded, and sailed on *Alpha Helix*. In each case, though, when it came to studying the ocean, the ship was a vital tool of scientific practice and of scientific authority.

But these researchers did more than define a new kind of ship, and a new kind of field. By taking their research onto the surface of the deep, they redefined the ocean itself. To the voyager who sailed across it, the sea had long been a highway, sometimes a battlefield, or perhaps a barrier. For all its literary symbolism as place to try one's courage and pluck, it remained a two-dimensional surface that reflecting the society that sent out the ships and the souls of the individuals who sailed them. Sounding made the sea three dimensional.

Sailors had of course been sounding for centuries, feeling towards coastlines where shelves of land seemed suddenly to appear, like steps at the edge of deep pool that let the wader ease their way into a swim that might otherwise seem daunting. But the bottom of the deep sea was left to speculation and surmise until Maury's lieutenants touched it and, with John Brooke's sounder, brought bits of it home. Maury's bathymetrical maps of the bottom of the Atlantic were wildly incomplete, based as they were on a dozen or so points of varying and sometimes questionable accuracy spread over millions of square miles. "Nothing," as Wyville Thomson observed, "can give a more erroneous or exaggerated conception" of the ocean basin than Maury's charts. Except that that erroneous conception was the start of a new, and increasingly accurate, remaking of the ocean basin as geography. Thus Thomson's allowance that Maury's chart was, "in a certain sense correct."[1] As Thomson and Prince Albert and Fritz Spiess and his crew and all the others who have been elided here contributed their soundings and dredge hauls and core samples, those dozen points became hundreds and thousands and millions. Together they constituted a scientific, and, importantly, a technological, reimagination of the ocean.

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1 Thomson, Carpenter, and Jeffreys, *Depths of the Sea*, 235.

The technological ocean could only be understood, these researchers asserted with every expedition proposal and results volume, from the deck of a ship. Oceanographers increasingly began to define themselves as scientists who go to sea. By the 1950s this had become such a standard of practice that American biologists demanded ships with seagoing capabilities not, in truth, because they intended to do work on the deep ocean, but because in order to define themselves as oceanographers and thus compete for the funding and institutional prestige involved in oceanography, they had to demonstrate their willingness and ability to go to sea.

In the twenty-first century, the ocean is most frequently studied in concert with the atmosphere as a global system. It is a system not unlike the clockwork ocean described by Matthew Fontaine Maury in the mid-1850s, with its jewels and movements and mechanisms (though it is interesting to wonder whether the addition of dynamical methods and the mathematization of chaos would have repelled Maury or increased his sense of wonder). In order to study the complicated dance of wind and current across the globe, the practices—or at least the practitioners—of ocean science have for several decades been shifting shoreward. Increasingly, they rely on large sets of data gathered from satellites, remote from both ocean and observer, and from networks of sensors mounted on buoys, drones, and even large marine fauna. Researchers manipulate this data from their desktop computers. For many purposes, the laboratory has thus become a truly placeless place, a virtual place, housed in a machine and accessed via a keyboard that could as easily be in Colorado as in Woods Hole or La Jolla.

In the twenty-first century, ships are becoming tools for the distribution and maintenance of data collection networks, rather than as vessels for the conduct of research in their own right.[2] Yet oceanographers largely retain their sense of themselves as field scientists, and ones whose field is vast, remote, and often hostile. They claim this heritage in much the same manner in which Thomson claimed to walk in Darwin's footsteps on St. Paul's Rocks, or Spiess to sound in *Dolphin*'s wake. We, say the oceanographers, stand on the decks of our predecessors, faces into the same waves. We study their sea. There is some irony in this, that their scientific efforts to represent the ocean as an historical, changeable, and changing place—a depiction that seems especially pressing to convey to a public and political audience in the face of snowballing Anthropogenic climate change—are wrapped intimately in their self-depictions as participating in a timeless tradition.

Witness filmmaker James Cameron's solo submarine dive to the bottom of the Mariana Trench in 2012, an almost-unprecedented act of three-dimensional ocean immersion via "vertical torpedo" that saw coverage in the global popular press. (In this, too, it was not unlike *Challenger*'s coverage in *Popular Science* and *Punch*.) Cameron's sub—a glorified sampler that grabbed sediment and biological samples via a robotic claw and a "slurp gun"—was named the *Deepsea Challenger*. His dive took place at Challenger Deep, named for the ship that first sounded it in the 1870s expedition described in chapter two, above, and was described firmly in the tradition of heroic science. Don Walsh, one of two people to make the only similar dive in 1960, was glad to "welcome him to the club."[3]

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[2] Antony Adler has argued that thus the "ship as laboratory" model is being supplanted by a new model of "ship as invisible technician", "The Ship as Laboratory: Making Space for Field Science at Sea," *Journal of the History of Biology* 47, no. 3, (August 2014): 338-339. See also Stefan Helmreich, *Alien Ocean: Anthropological Voyages in Microbial Seas* (Berkeley: University of California Press, 2009), 240-243.

[3] Ker Than, "James Cameron Completes Record-Breaking Mariana Trench Dive," *National Geographic News*, 25 March 2012. Accessed 19 March 2017. Online at

As the news coverage of Cameron's feat demonstrates, public engagement with ocean science simultaneously embraces the heroic with the technological. Whether or not the dive signaled a "renaissance in deep-sea exploration," as observing scientists hoped, their impulse to understand the dive's potential to engage public interest in ocean science is sound. In an increasingly tight funding world, the public must "buy in" if oceanographers are to successfully push for funding the expensive technologies of ocean science. No doubt this was the goal of British ocean scientists, too, when they offered the public a chance to name a planned $287 million polar research ship. Many thought the effort had backfired when the internet public rousingly lined up behind RRS *Boaty McBoatface*, but in truth it served the larger purpose of raising public awareness and engagement in a way no more sober and traditional name could have managed.[4]

Fittingly for the larger arc of technological study of the oceans, the popularly chosen name was assigned instead to a robotic submarine that will work in concert with the ship. Yet the traditional evocation of adventure and heroic exploration as inherent in the conduct of ocean science still found voice in recent headlines covering the sub's launch, such as *The Verge*'s "Boaty McBoatface's heroic journey to Antarctica begins today."[5] The technology of ocean science is thus rendered heroic even without a crew.

These two recent events that brought ocean science into the public eye underline the importance of ships as fundamental technologies of ocean science. Even if the missions of those ships shift away from carrying the scientists themselves to carrying and

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http://news.nationalgeographic.com/news/2012/03/120325-james-cameron-mariana-trench-challenger-deepest-returns-science-sub/

[4] Katie Rogers, "Boaty McBoatface: What You Get When You Let the Internet Decide," *New York Times*, 21 March 2016. Accessed 19 March 2017. Online at https://www.nytimes.com/2016/03/22/world/europe/boaty-mcboatface-what-you-get-when-you-let-the-internet-decide.html

[5] Alessandra Potenza and Elizabeth Lopatto, "Boaty McBoatface's heroic journey to Antarctica begins today," *The Verge*, 17 March 2017. Accessed 19 March 2017. Online at http://www.theverge.com/2017/3/17/14951020/boaty-mcboatface-antarctica-trip-climate-change-rrs-sir-david-attenborough

deploying their increasingly autonomous new technologies, they reinforce the necessity of that technological interface. They also point up the fact that the twenty-first century public is increasingly able to witness such feats through livestream video or Reddit ask-me-anything forums available via the cell phone and laptop technology that is rapidly becoming ubiquitous. The three-dimensional, technological global ocean is increasingly reimagined as an accessible place now thanks to these technologies, to Google Earth, to citizen science projects to classify crustaceans and sea worms. Members of the public can thus participate in ocean science and imagine themselves as part of its heroic tradition, even from their living room sofas.

Over the nineteenth and twentieth centuries, ships enabled scientists to access the deepest oceans, changing them from a hidden realm of timeless stillness to a knowable place, where currents move the water and life roams the bottom, subject to the prying eyes of the technologies of science. Ships became in the process expected inhabitants of the scientific ocean. Perhaps, then, this sense of the ocean as a technological place will allow the public to recognize the ocean's changeability. As Maury's charts and wooden screw corvettes now seem quaint as technologies of representation and investigation, so might the view of the ocean as unchangeable be rendered obsolete. As the ocean becomes a place best represented in three, digital dimensions and roamed by heroic yellow automata, perhaps it will also be reimagined in the public mind as a place that the technologies of science can know, and which science has shown to be changeable and changing.

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