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The Rise of Oceanography in the United States, 1900-1940

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by

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Abstract

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Around 1900, oceanography was not an established scientific field. Even though scientific surveys of the oceans had been done quite steadily in Europe and the United States for several decades, those efforts were not yet organized into a single scientific discipline. A new trend in the study of the sea began to emerge when scientists realized that the oceanic phenomena were complexly interrelated and that it was impossible to understand one without knowing the others, which happened first in Europe and then in the United States. Endeavors to form a single science of the oceans began to appear in the early twentieth century.

This dissertation is a study of the formation of oceanography in the United States roughly in the first four decades of the twentieth century. It traces the institutional as well as intellectual changes that took place mainly in the two American centers of oceanographic research—the Scripps Institution of the University of California and the Woods Hole Oceanographic Institution. The Scripps Institution of Oceanography, which started as a modest marine biological station in 1903, slowly evolved into an oceanographic institute devoted to this new science. The Woods Hole Oceanographic Institution, officially founded in 1930, was a latecomer but had many years of prehistory worth careful historical study. In the period between 1900 and 1940, American scientists came to understand the need for systematic study of the sea, and developed institutional structures and practices that enabled them to implement that understanding. Oceanography became a legitimate scientific discipline.

American oceanography underwent substantial changes during World War II.

Navy sponsorship brought about tremendous changes in the scale and character of the enterprise. However, it must be remembered that the fundamental framework of American oceanography was formed before the war. This dissertation aims to show the importance of that period in the history of oceanography.

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Acknowledgements

I became familiar with such names as Scripps and Woods Hole when I was an undergraduate student of oceanography at Seoul National University in Korea. It was natural that I became interested in the history of modern oceanography as a graduate student of history of science, and I began to think about writing my Ph.D. dissertation on it early in my first year at Berkeley. I had chances to talk about my dissertation topic with John Lesch, Roger Hahn, Cathryn Carson, and the late James Kettner, and they all encouraged me to work on the topic I had in mind—history of oceanography in the United States. Thanks to them I could be confident that it would make a good dissertation topic.

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INTRODUCTION

Oceanography as a scientific discipline did not exist until the end of the nineteenth century. Although various aspects of the ocean often attracted scientists around the world, systematic study of them as a single, unified scientific field began to appear only at the turn of the twentieth century. Few people understood the need for such a science, and the study of the ocean and its inhabitants was done fragmentarily here and there without the clear aim of understanding the full oceanic phenomena. In the United States, the institutionalization of oceanography took place in the first half of the twentieth century, first on the west coast and then on the east coast. By the 1940's, the science of oceanography was well defined and well organized, with its firm institutional bases and research network, as its contributions to the war effort during the Second World War testify.

If oceanography as a scientific discipline did not exist until the late nineteenth century, who were the scientists engaged in the study of natural phenomena of the sea? There were some physicists and geophysicists who were interested in the physical aspects of the ocean such as tide, currents, and waves. Often, these physical scientists tried to apply theories of general physics to oceanic phenomena. Other scientists approached the study of the sea from a more practical point of view. Their purpose was to facilitate faster and safer navigation of merchant and naval ships by studying the topography of the ocean floor and regional currents. They carried out extensive depth and temperature measurements at various points at sea, which were translated into improved sea charts containing information on underwater topography and the oceanic current system. This practical study of the physical aspects of the ocean was often called hydrography, and these men—hydrographers—usually worked for their governments and navies.

Biological phenomena of the sea also interested many scientists. Naturalists were intrigued by marine flora and fauna, large and small. They were unfamiliar with the diverse life forms of the sea, and those marine animals living in the deep sea, in particular, had always belonged to the domain of mystery. Natural historians were first delighted at the discovery of new species at sea. But, as the theory of evolution developed in the mid-nineteenth century, marine organisms began to have much greater meaning for general biology. Animals and plants that had previously been found only in fossil forms were found at sea and biologists pondered on their meaning for evolution. Marine organisms were also popular objects for laboratory study and experimentation, both because of their theoretical importance and because of their simple structure which enabled biologists to manipulate them easily. Marine biology became more important by the late nineteenth century as scientists began to think that a systematic study of marine organisms would lead to the solving of the fisheries problems. The yearly fluctuation of fisheries yields and the concern for depletion of major crop fishes led the governments and the fishery industry to depend heavily on the work of biological scientists.[1] To increase the efficiency of fisheries it was believed that scientific understanding of the life history of fish, as well as the knowledge of their food and environment, was essential. Marine biology was expected to provide such knowledge.

The rise of oceanography as an independent scientific field was a process of gathering together these scientific workers of diverse interests and organizing the scattered knowledge to form a single discipline devoted to the study of the ocean as a whole. Those engaged in various aspects of ocean sciences lacked the idea of working in the same field, as they thought they were apparently studying subjects of their own scientific fields. In most cases, they retained their identities as physicists, hydrographers, natural historians, or biologists even when they were studying the ocean, and only a few wanted to call themselves oceanographers. The idea of an established science of oceanography did not yet exist. Without the shared idea of oceanography being a unified science of the sea, it was natural that hydrographers, physicists, and biologists each pursued their own study with the framework and motives given by their main fields. Therefore, those scientists seldom, if ever, worked together with workers in other

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[1] The fishery industry's attitude toward the scientific approaches to fisheries was not always positive. It was often feared that scientific discoveries would lead to regulations on fishery production. Arthur F. McEvoy, *The Fisherman's Problem: Law and Ecology in the California Fisheries, 1850-1980* (Cambridge: Cambridge University Press, 1986). See also Harry N. Scheiber, "Modern U.S. Pacific Oceanography and the Legacy of British and Northern European Science," in Stephen Fisher, ed., *Man and the Maritime Environment* (Exeter, England: University of Exeter Press, 1994), 36-75.

scientific fields.

The sciences of the ocean could be unified only after scientists understood the fact that the oceanic phenomena were all interconnected. The idea of complexity and interconnectedness of oceanic phenomena began to spread widely around the turn of the twentieth century, first in Europe. And scientific leaders who articulated this idea began to appear also in the United States. They realized, from their own research experiences as well as from the work of their European colleagues, that it was impossible to understand one aspect of the sea satisfactorily without knowing other aspects that were so closely connected with it. Thus, they felt the necessity of bringing together scientists of several different fields, and they strongly argued for the need for cooperative work in ocean sciences.

The project of making a unified science of oceanography had to begin with defining that science. T. Wayland Vaughan and Henry B. Bigelow, in particular, did this task of defining oceanography for the American scientific community in the 1920's.[2] They contended that oceanography was a comprehensive scientific discipline comprised of several sub-branches such as physical oceanography, chemical oceanography, marine biology, and marine geology. Both Vaughan and Bigelow admitted that each branch had to be given some independence but, at the same time, they emphasized the inevitable dependence of each on the others. Behind their claims of oceanography as a sum of interconnected branches was the holistic approach they took in seeing the ocean. The ocean could not be properly understood, scientifically, unless all aspects of its natural phenomena were considered altogether; dealing only with a part of the vast oceanic phenomena could never bring about meaningful results.

Oceanography, now well defined, could not survive as an established scientific discipline unless it was given a firm institutional basis. American oceanographers thought that oceanography had to be established at universities. Universities and colleges were thought to be the main locus of scientific research and education at that time. Therefore, in order to acquire the status of an independent, established scientific

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[2] T. Wayland Vaughan, "The Scripps Institution—Its Present Work in Oceanography and Suggestions for Its Future Development" (1924), Records of the SIO Office of the Director (Vaughan), 1924-1936, Scripps Institution of Oceanography Archives, University of California, San Diego; Henry B. Bigelow, *Oceanography: Its Scope, Problems, and Economic Importance* (Boston: Houghton Mifflin, 1931).

discipline like physics, astronomy, chemistry, geology, and biology, oceanography, too, had to find its place within American universities and colleges.[3] Particularly, it was essential to have a department of oceanography, or an equivalent degree program in oceanography, for the nurturing of the next generation of American oceanographers. Those who were working in areas of oceanography at that time were educated and trained in other natural science fields, and when they became interested in the ocean they had to be self-educated in knowledge and techniques of marine sciences. It was by no means an effective way of educating oceanographers, and it was hard for those who trained themselves as oceanographers to have comprehensive knowledge of all the branch fields of oceanography. If students could be educated in graduate and undergraduate programs at universities and granted degrees in oceanography, oceanography would be placed on a firmer ground as an institutionalized scientific discipline.

Aside from degree programs at university campuses, seaside oceanographic research facilities were also necessary for proper education. They often had to be built outside the university campuses because of the fact that not many campuses had seaside locations appropriate for oceanographic field work. Ocean scientists had to have easy access to the sea and marine organisms, but the locations of most universities did not meet this condition. Therefore, separate marine scientific stations and laboratories were built by the seaside. These facilities were essential for education of students and young researchers, who had to be trained, as it was firmly believed, in the field. The seaside stations had to have their own ships that could take researchers and students out to the high seas. All of these required larger financial support for oceanography than most other scientific fields, and American ocean scientists always had to struggle for more money and stable patronage throughout the period covered in this dissertation. Larger financial demand for oceanographic research and education was one of the main reasons for the delayed institutionalization of oceanography in the United States, as elsewhere in

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[3] In detail, Vaughan and Bigelow took different approaches regarding graduate education in oceanography. Vaughan, director of the Scripps Institution of Oceanography, made his institute a department of oceanography of the University of California. On the other hand, the Woods Hole Oceanographic Institution was an independent institution not connected to a single university, and Bigelow tried to stimulate founding and strengthening of oceanographic programs at many different universities and colleges by providing students with fellowships, assistantships, and chances to participate in the field research at WHOI.

the world.

In this dissertation, I will focus on the process of institutionalization of oceanography and trace how this new science took its form in the United States between about 1900 and 1940. Institutionalization of oceanography has long been considered to be one of the main issues for historians of oceanography. And oceanographic institutions, in particular, have received much attention. For instance, Eric Mills wrote "Oceanography is fundamentally social, thus it is not surprising that attention has been paid to marine science institutions (my discussion excludes biological stations) in major publications since 1966."[4] But the wide interest in individual institutions failed to address more fundamental problems such as how and when oceanography became an established science, when marine scientists began to call themselves oceanographers, how oceanography became a university-based science, how oceanographers were educated and trained, etc. Mills also pointed out the importance of such questions:

> Professionalism implies a community of practitioners sharing a body of knowledge, common ideas or goals, and increasingly, standards for acceptance into the community. The evidence suggests that such a community was rudimentary, at best, as late as 1908. To talk or write simply of "precursors" of oceanography without examining these problems, or to take "oceanography" as given rather than representing an unsolved problem, as too many have done since 1966, skirts many fascinating historical problems of wide interest. . . . As I have suggested, professions and institutions are closely linked. Examining institutions should show us how scientists regarded their work or planned for its future and, often, may indicate the relationships between science and the state. In my opinion, during the past few years there has been an unbalanced emphasis on marine stations, ignoring the broad range of marine science institutions that came into being after the middle of the 19th century.[5]

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[4] Eric L. Mills, "The Historian of Science and Oceanography after Twenty Years," *Earth Sciences History*, 12 (1993): 5-18. The quotation is from p. 9.
[5] Ibid.

In this dissertation, the process of oceanography's institutionalization in the United States will be examined concentrating on the two most famous American oceanographic institutions—the Scripps Institution of Oceanography and the Woods Hole Oceanographic Institution. Even though emphasis will be placed on the two oceanographic institutions' early history and a handful of people who contributed to the founding and development of them, it is nevertheless not merely a history of those two institutions. It aims to show how American scientists struggled to build their science, how relevant marine science fields came to be unified, and oceanography became an established scientific discipline in the United States, having its own institutional bases for continued research and education of the next generation of oceanographers. In other words, this dissertation will explore how the science of oceanography came to exist in America.

The period between 1900 and 1940 is very important, therefore, in the history of oceanography because it was during these years that oceanography became a scientific discipline like other major scientific fields. Yet, the institutionalization of oceanography in the United States in this period has not been well represented in recent historical literature. Many historians have been actively investigating the link between oceanography and the military since the time of World War II, while others were still writing about the previous period of great oceanic expeditions.[6] Post-World War II expansion of American oceanography, in particular, has greatly intrigued scholars. I do not mean to assert that there has been no historical writing at all about oceanography during this period but, evidently, its importance as the formative years of American oceanography has not received its due attention.

Oceanography's intimate relationship with the U.S. Navy developed quickly during the years of World War II and strengthened thereafter.[7] From the beginning of

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[6] For example, Margaret Deacon's classic book, *Scientists and the Sea, 1650-1900: A Study of Marine Science* (Brookfield, Vt.: Ashgate, 1997) ends around 1900. For more recent examples of historical scholarship focusing on the nineteenth-century ocean sciences, see Margaret Deacon, Tony Rice and Colin Summerhayes, eds., *Understanding the Oceans: A Century of Ocean Exploration* (London: UCL Press, 2001) and Helen M. Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea* (Cambridge, Mass.: Belknap Press of Harvard University Press, 2005).

[7] See for example, Ronald Rainger, "Science at the Crossroads: The Navy, Bikini Atoll, and American Oceanography in the 1940s," *Historical Studies in the Physical and Biological Sciences*, 30 (2000): 349-372; Rainger, "Constructing a Landscape for Postwar Science,"

scientific activities in the United States in the realm of ocean sciences, the Navy had been a close partner cooperating in many aspects, most of all in providing its ships for scientific research at sea. Yet the cooperation, and occasional direct financial support, had never been so powerful as it was in the World War II era. The funding for oceanographic research scaled up tremendously during the war, and oceanography became a genuine "big science" almost incomparable with its state before the wartime growth. The intimate symbiosis of the U.S. Navy and American oceanography has continued until today, and it is no exaggeration to say that the relationship determined, in many ways, the direction of oceanography's development in the past half century. Therefore, it is quite understandable that historians have paid more attention to that period of amazing transformation and growth. It is indeed impossible to understand today's oceanography without looking closely at the events in the 1940's and 1950's.

There is one important question that the historians of oceanography in World War II and the postwar years fail to address: how could American oceanographers contribute to the wartime efforts as they did during World War II? Was the scientific understanding of the seas always crucial for victory in naval battles? No. It is historically wrong to claim so. On the contrary, World War II was an exception, an unprecedented event in history. Only about two decades before, during the First World War, American ocean scientists' contributions were made mostly in the realms outside of the direct military efforts. As I mention in Chapter 2, American ocean scientists mainly participated in the study led by federal and state agencies for the better production of more food during the Great War. Scripps scientists, more than others, were mostly marine biologists, and at a time when food and other biological resources were badly needed it was natural that they were positioned to undertake that line of research. It certainly was an important contribution, but it was a very different kind of wartime job

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Minerva, 39 (2001): 327-352; Rainger, ""A Wonderful Oceanographic Tool": The Atomic Bomb, Radioactivity and the Development of American Oceanography," in Helen M. Rozwadowski and David K. van Keuren, eds., *The Machine in Neptune's Garden: Historical Perspectives on Technology and the Marine Environment* (Sagamore Beach, Mass.: Science History Publications, 2004), 93-131; Naomi Oreskes, "Laissez-tomber: Military Patronage and Women's Work in Mid-20th-century Oceanography," *Historical Studies in the Physical and Biological Sciences*, 30 (2000): 373-392; Gary E. Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment* (College Station: Texas A&M University Press, 2001); and Jacob Darwin Hamblin, *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005).

than we expect of oceanographers today. Therefore, it becomes necessary to ask what happened in the period between the two world wars. To understand the events and changes that occurred in the preceding few decades would provide us with a better view of the development of oceanography in the United States, and worldwide, since the time of World War II.

Even though this dissertation covers the crucial period of oceanography's institutionalization, it by no means covers the whole story. The new, more comprehensive, approach in the study of the ocean appeared first in Europe and Great Britain. Especially in the Scandinavian nations in the late nineteenth century, there arose a scientific movement which stressed the importance of combining physical and biological knowledge in understanding the natural phenomena occurring in the sea.[8] The scientists who first conceived this idea were the Scandinavians seeking to solve the problem of fishery fluctuations by adopting scientific methods. They realized that without the knowledge of oceanic current systems, ecology of fish stocks could hardly be understood properly because fish eggs and larvae cannot move by themselves but drift along the flow of the seawater. In order to understand the life histories of important fish stocks, it was necessary to study physical oceanography. In the Northern European fishery studies, thus, the unified science of modern oceanography had one of its origins.

The new European oceanography did not cross the Atlantic Ocean immediately. Henry Bryant Bigelow, writing in the late 1920's, remarked that there was a period of stagnation in the march of American ocean sciences around the turn of the twentieth century, at the time when there was a great leap forward in Europe.[9] While leading European oceanographers were attacking the scientific and practical problems of the ocean with novel methodologies, Americans still clung to the nineteenth-century mode of marine sciences. When pioneers in American oceanography, such as William Emerson Ritter, Charles Atwood Kofoid and Henry Bigelow began to renew American oceanography by adopting new directions in the early twentieth century, they seemed to have gotten some influence from their European colleagues. Although it cannot be

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[8] Susan Schlee, *The Edge of an Unfamiliar World: A History of Oceanography* (New York: E.P. Dutton, 1973), 170-205.

[9] Henry B. Bigelow, "Report on the Scope, Problems and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies," Report of the Committee on Oceanography of the National Academy of Sciences, Frank R. Lillie, Chairman. 1929, p. 94.

asserted with full certainty that their oceanographic work was directly influenced by European models, circumstantial evidence shows that it was very probable that they imported the new ideas from across the Atlantic. For example, Ritter visited Europe just before he opened the laboratory of the San Diego Marine Biological Association in 1903 with a program of "marine biology," the main idea of which was previously unknown in the United States. Likewise, Kofoid traveled around Europe visiting important marine stations when the San Diego Marine Biological Association was in the process of setting up in its early years. Bigelow, too, confessed that he had a conversation with British oceanographer Sir John Murray shortly before he embarked on the study of the Gulf of Maine.[10] Thereafter, there are many evidences of frequent exchange between the oceanographic communities in the United States and the European countries, an exchange of scientific ideas as well as personnel throughout the period that this dissertation covers.

Another important aspect of oceanography's historical development that is not fully addressed in this dissertation is fisheries science and its relationship with academic oceanography. As I have just mentioned above, modern oceanography's beginning in Europe was closely intertwined with the scientific efforts to solve the fisheries problems. By 1900, there also existed in the United States a generation-old tradition of dealing with the problems of fisheries with the methodologies of natural science, which can be traced to the first U.S. Fish Commissioner Spencer Fullerton Baird.[11] But American fishery scientists seem to have been much less influential in the development of oceanography than their Scandinavian and British counterparts. This is probably because of the tendency in the United States, which had existed from the beginning of its history, to be extremely cautious about spending federal money in scientific projects from which not so much practical outcome could be expected. (In Europe, fisheries studies were in most cases supported by governments.) Therefore, the work of the U.S. Fish Commission, and later the Bureau of Fisheries, tended to focus on practical matters which did not have much meaning for marine scientists. That was probably the reason

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[10] Helen Raitt and Beatrice Moulton, *Scripps Institution of Oceanography: First Fifty Years* (San Diego: Ward Ritchie, 1967), 3-22; Charles A. Kofoid, *The Biological Stations of Europe* (Washington, D.C.: Government Printing Office, 1910); Henry B. Bigelow, *Memories of a Long and Active Life* (Cambridge: Cosmos Press, 1964), 23.

[11] Dean C. Allard, *Spencer Fullerton Baird and the U.S. Fish Commission* (New York: Arno Press, 1978).

that the main actors in this dissertation usually did not conceive the problems of fisheries as an important factor in their scientific endeavors, quite unlike their European colleagues, especially those who were engaged in the programs of the International Council for the Exploration of the Sea.[12] One of the few exceptions might be William F. Thompson, who was director of the famous school of fisheries studies at the University of Washington.[13] This dissertation does not cover his story, but concentrates on those of the Scripps Institution and the Woods Hole Oceanographic Institution.

My dissertation comprises the following six chapters. The first chapter is an overview of the American marine science tradition in the nineteenth century, and sets the stage for the ensuing story of the early twentieth-century development of American oceanography. Here I mention briefly the main achievements of American scientists in the realms of hydrography, marine biology, and other branches of ocean sciences. I emphasize the chain of marine biological stations throughout the coasts of the United States as some of them would later become homes for early American oceanographers.

The second chapter deals exclusively with the Marine Biological Association of San Diego, which changed its name to the Scripps Institution for Biological Research in 1912 and then to the Scripps Institution of Oceanography in the mid-1920's. This seaside station, founded in 1903 by the University of California biologist William E. Ritter, began as an ordinary marine biological station but soon took a rather unique direction clearly distinguishable from other stations flourishing at that time in the United States. I seek to trace the unusual path of this institution and to find an answer to the question why the crucial decisions were made at the critical moments of its early development.

The story of the Scripps Institution continues in the next chapter where I

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[12] Helen M. Rozwadowski, *The Sea Knows No Boundaries: A Century of Marine Science under ICES* (Seattle: University of Washington Press, 2002). See also Schlee, *The Edge of an Unfamiliar World*.

[13] For Thompson's scientific career, see Harry N. Scheiber, "Modern U.S. Pacific Oceanography and the Legacy of British and Northern European Science," in Stephen Fisher, ed., *Man and the Maritime Environment* (Exeter, U.K.: University of Exeter Press, 1994), 36-75; Scheiber, "Pacific Ocean Resources, Science, and Law of the Sea: Wilbert M. Chapman and the Pacific Fisheries, 1945-70," *Ecology Law Quarterly*, 13 (1986): 390-395; J. Richard Dunn, "William Francis Thompson (1888-1965): A Preeminent Fishery Biologist of the Early and Mid Twentieth Century," *Marine Fisheries Review*, 63 (2001): 1-4; Dunn, "William Francis Thompson (1888-1965) and His Pioneering Studies of the Pacific Halibut, *Hippoglossus stenolepis*," *Marine Fisheries Review*, 63 (2001): 5-14; and Dunn, "William Francis Thompson and the Dawn of Marine Fisheries Research in California," *Marine Fisheries Review*, 63 (2001): 15-24.

consider its turn from a biological station to an oceanographic institution. This chapter is mostly a story of the innovations that the institution's second director T. Wayland Vaughan initiated. Vaughan intended to transform the Scripps Institution into a fully oceanographic institute. Vaughan's intellectual background, his ideals as well as his shortcomings, are the main themes in this chapter.

In Chapter 4, the main focus shifts to the American east coast where oceanographic work lagged behind the west at least until the late 1920's. One notable exception was Harvard biologist Henry Bigelow's Gulf of Maine study, which was prosecuted in conjunction with the U.S. Bureau of Fisheries.[14] The situation dramatically changed with the founding of the Woods Hole Oceanographic Institution which opened officially in 1930.

Chapter 5 is mainly an analysis of the discourse that went on at the Committee on Oceanography of the National Academy of Sciences, whose conclusion eventually led to the founding of the Woods Hole Oceanographic Institution. The Committee's report written by its secretary Henry Bigelow and submitted to the Academy in late 1929 is the main target of analysis here as this comprehensive document played a crucial role in the development of American oceanography.[15] Leaders of the American scientific community knew quite well the recent, very successful European efforts and were concerned about the United States' failure to contribute to international cooperative research in the northern Atlantic Ocean. They sought to find a way to remedy the situation and recover their country's ability in the domain of the marine sciences by founding a new east-coast oceanographic institute. This report contains not only the committee members' diagnosis of the situation of American oceanography at that time and the reasons for the proposal to erect an east-coast oceanographic institution, but also a more general overview of the important issues of contemporary oceanography, both European and American.

Finally, Chapter 6 briefly covers the period between the founding of the new oceanographic institution at Woods Hole, Massachusetts, and the United States' participation in World War II. By 1930, the general infrastructure of American oceanography was well established, and a series of high-quality field researches

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[14] Jeffrey P. Brosco, "Henry Bryant Bigelow, the U.S. Bureau of Fisheries, and Intensive Area Study," *Social Studies of Science*, 19 (1989): 239-264.
[15] Bigelow, "Report on the Scope, Problems and Economic Importance of Oceanography."

continued in the 1930's, particularly at Woods Hole and Scripps. The kind of oceanographic work that T. Wayland Vaughan and Henry Bigelow actively advocated in the 1920's could be conducted in this period and was firmly built into the system. It is true that the financial situation for oceanographic institutions and research projects was still largely unstable at that time and the scale and quantity of oceanographic activities were meager compared with those in the post-World War II era. Nevertheless, it was a time when the basic characteristics of American oceanography were established. Oceanography's growth and contributions during the war cannot be understood properly if the pre-war developments are not duly considered.

This study, therefore, aims to fill one of the historiographical gaps in the history of oceanography, and thereby contribute to our better understanding of this important scientific discipline. Oceanography is an indispensable natural science today as the oceans are believed to be the key to serious problems such as the global climatic change, the deficiency of energy and food sources, etc. Knowing the past of oceanography will help us to better understand the role, ability, and limits of this important science today.

CHAPTER 1
A Magnificent Chain of Biological Stations: American Marine Biological Stations and the Beginnings of Marine Science in the United States

American oceanography did not appear from nothing. Beginning in the mid-nineteenth century, American scientists actively engaged in the study of the ocean. The federal government took the initiative in the effort with its practical aims of enhancing the country's naval, commercial, navigational, and fisheries capacities. The scientific work done at such institutions as the United States Coast Survey, the Depot of Charts and Instruments of the Navy, and later at the United States Fish Commission Laboratory, as well as the U.S. Exploring Expeditions proved the interest and ability of the American scientific community in the domain of marine science. Their scientific contributions were well acknowledged also in Europe and were, indeed, valuable for emerging marine science as a whole. Nevertheless, the federal government was not a consistent supporter of science in the nineteenth century. Direct support to scientific work was often considered unconstitutional, and the scientific projects at the federal agencies could expect only indirect and limited financial backing from the government.[1]

What proved to be more crucial to the development of marine science in the United States was the proliferation of marine biological stations, a notable phenomenon in the late nineteenth and early twentieth century. After the model of earlier, successful marine biological stations in both Europe and the United States, a considerable number of seaside biological laboratories were built in the North American continent in various shapes and sizes. Some emphasized education of school teachers and beginners in biological sciences while others put more emphasis on advanced research by university-trained professionals. Some stations became centers for experimental and laboratory biology whereas others were built with the more traditional aim of understanding the

[1] A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge, Mass.: The Belknap Press of Harvard University Press, 1957).

natural history of domestic fauna and flora. Some of these stations belonged to universities and some were open to everyone interested in marine biology. Whatever their characteristics, these seaside stations all reflected the great interest of contemporary biologists in marine organisms, and they helped to turn the attention of young American scientists to the sea.

Among these American marine stations few showed any interest in the study of the ocean as a whole, and biology alone was studied and taught at most marine biological stations. Many marine biologists did not even care about the living environment of the organisms they studied in the laboratory. Still, the stations were very important in the history of the marine sciences. They provided marine sciences with a permanent home for continuation of research for the first time in history without, in most cases, government interference. In the previous decades, and centuries, the development of ocean science often had to stop at important stages for lack of continued support and interest. After decades of gaps, followers always had to start from the beginning and do things all over again. Historian of oceanography Margaret Deacon aptly remarked on the meaning of the nineteenth-century marine biological stations that

> Without facilities for collecting observations, without opportunities for work on shore and without a recognized career structure, it was difficult if not impossible for people to make marine science their life's work. Marine biology became an exception in the late nineteenth century when academic zoologists could specialize in marine life and there were opportunities for full time research in the marine stations and the fisheries laboratories. In the other branches of marine science such opportunities were almost nonexistent. H. R. Mill described how he had had to give up marine science to be able to earn his living and this dilemma faced most of his contemporaries as well.[2]

The situation was similar in Europe and in the United States. Establishment of biological stations signaled a new phase in the history of marine sciences.

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[2] Margaret Deacon, *Scientists and the Sea, 1650-1900: A Study of Marine Science*, 2nd edition (Aldershot, U.K.: Ashgate, 1997), xiii.

This chapter will explore the beginning of the marine science tradition in the United States with an emphasis on the seaside marine biological stations in the late nineteenth and early twentieth century. Attention will be given, first, to the Marine Biological Laboratory in Woods Hole, and then to a group of various smaller stations, such as the one at the Dry Tortugas in Florida, that formed a chain of marine stations in the United States.

1. The Beginning of American Marine Science: U.S. Coast Survey and the Navy

In the early nineteenth century, the United States government established two agencies devoted mainly to surveying and charting the nation's coastal seas and the trading routes of the two great oceans, Atlantic and Pacific. The Coast Survey, led by Ferdinand Rudolph Hassler, was one of the first scientific ventures under the auspices of the young United States, and its early history shows the confusion and difficulty involved in early federal science.[3] Hassler, a Swiss immigrant, was the first person who began the systematic study and survey of the sea in the new nation. Supported by the American Philosophical Society of Philadelphia, Hassler approached President Jefferson with his plan of surveying the Atlantic Coast. He was an expert of geodetic survey and the French metric system, who had previous experience working for the Canton of Bern in Switzerland. At that time, merchant ships and the U.S. Navy relied on "imperfect and erroneous" charts drawn by Europeans, and the need for accurate and complete ones based on a series of new, scientific surveys was a pressing issue among the commercial circles of the coastal states. Hassler's plan was accepted and the Coast Survey project officially began in 1807.

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[3] Dupree, *Science in the Federal Government*, 29-56; Susan Schlee, *The Edge of an Unfamiliar World: A History of Oceanography* (New York: E.P. Dutton, 1973), 23-79; and for Hassler's biography, see Florian Cajori, *The Chequered of Career Ferdinand R. Hassler, First Superintendent of the United States Coast Survey* (Boston: Christopher Publishing House, 1929). See also, Thomas G. Manning, *U.S. Coast Survey vs. Naval Hydrographic Office: A 19th-Century Rivalry in Science and Politics* (Tuscaloosa and London: University of Alabama Press, 1988).

The actual survey work did not begin until 1816, however. Because of political and bureaucratic confusion, Hassler had to wait until 1811, spending his time teaching mathematics at the U.S. Military Academy at West Point. He then left for England in order to secure instruments needed for the survey. There he made orders and supervised the making of such essential surveying instruments as chronometers, clocks, a theodolite, telescopes, barometers, thermometers, balances, and a base-line measurement apparatus. Returning to the Unites States, he embarked on preliminary survey work of the northeast coast in 1816. Soon after finishing the second year's survey in 1817, Hassler had to face pressures from the Government and the Congress asking for quick practical results. The politicians did not understand the nature of geodetic survey while Hassler wanted to take time to do a thorough scientific survey. Moreover, some people in the Navy, such as Cheever Felch, claimed that they could do a better job in less time, which certainly impressed the politicians. In the meantime, Congress passed an act which allowed only military personnel to work at the Coast Survey. Ultimately, Hassler was removed from the project and the survey work fell to the hands of the Navy.

Hassler returned to the Coast Survey in 1832 after fifteen years away from the job. By that time, members of the government and congress had better understanding of the science-based survey. And the changed political situation demanded better geographical information, while the fifteen-years' survey work led by the Navy had produced only worthless results. It was readily agreed upon that there was no better person than Hassler to head the revived Coast Survey. Hassler had already been back in the government since 1830, working for the Treasury Department examining the standard weights and measures, a job he continued until his death in 1843. When Congress revived the coast survey in 1832, he became its superintendent. Again, the Coast Survey was not considered a permanent agency and Hassler himself did not claim that it was. But the political situation was much more favorable and he could even begin some scientific work such as examining temperatures, currents, salinities, and bottom deposits of the sea as well as measuring depths.

Despite the expectations for a prompt publication of the new charts, Hassler did not allow premature ones to be published. Such an attitude of his eventually made the congressmen tired in spite of the earlier excitement over the Survey's discovery of an alternate deep-water channel into New York harbor. Although the Survey had accumulated enough data on the Atlantic coast, it published few charts under Hassler before his death in 1843.

Alexander Dallas Bache succeeded Hassler at the Coast Survey as the second superintendent in 1843 and led the agency for twenty four years.[4] He was competent both in leading scientific survey work and in dealing with the congress, and eventually "made that organization into the largest, most powerful scientific agency within the government."[5] Bache was great-grandson of Benjamin Franklin and he graduated from West Point, where he was trained in physics and chemistry. He resigned from the Army to become professor of natural history at the University of Pennsylvania. When he became the superintendent of the Coast Survey, he claimed hydrography to be one of the main duties of the Survey, which included "sounding, marking shoals and rocks, measuring the direction and velocity of inshore currents, and maintaining tide gauge stations."[6]

Bache, who considered himself a scientist, immediately included in the Survey's work the scientific study of the sea. In addition to the physical study of the ocean, which he and the members of the Survey could handle, natural history of bottom sediments was also studied, often in cooperation with academic scholars outside the agency. Sounding the ocean depth usually brought up sea-floor sediments as by-products, and Bache ordered that all the bottom samples had to be collected and classified. Some of the samples were sent to Jacob W. Bailey, professor of chemistry, mineralogy and geology at the U.S. Military Academy. Bailey was delighted to find out that shells and skeletons of animal planktons constituted the offshore seafloor deposit. Louis Agassiz, who was interested in marine biology, was also often invited to accompany the Coast Survey and had chances to collect and examine marine organisms. Moreover, Agassiz studied the biological and geological characteristics of the coastal seafloor, and discovered clues to extend his glacier theory to the sea. His close friend Louis François de Pourtalès, also a Swiss, joined the Survey and became head of the tidal division. His main interest was in marine zoology and geology, however, and after Bailey's death in 1857 he took charge of the Survey's seafloor samples. Although the academic work by these scientists

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[4] Dupree, *Science in the Federal Government*, 100-105, 115-119; Schlee, *The Edge of an Unfamiliar World*, 23-79. See also Hugh Richard Slotten, *Patronage, Practice, and the Culture of American Science: Alexander Dallas Bache and the U.S. Coast Survey* (Cambridge: Cambridge University Press, 1994).

[5] Schlee, *The Edge of an Unfamiliar World*, 25-26.

[6] Ibid., 40-41.

appealed little to the politicians in Congress, they contributed to the prestige of the agency within the scientific community on both sides of the Atlantic.

The United States Navy also contributed to the science of the ocean by establishing the Depot of Charts and Instruments in 1830 and organizing the United States Exploring Expedition that began in 1838 and lasted for three years and ten months. The Depot of Charts and Instruments, like Coast Survey, was founded not for scientific purposes but for very pragmatic aims.[7] Its original mission was to take care of and test navigational instruments and charts. This agency, headed by Lieutenant L. M. Goldsborough, was patterned after the Dépôt des Cartes, Plans, Journaux et Mémoires Relatifs à la Navigation of France and the British Hydrographic Office.[8] Until the early 1840's, the Depot put more emphasis on astronomical observations needed for testing navigational instruments rather than hydrographic work, which would later become its central concern under Matthew Fontaine Maury.

Meanwhile, a plan for an exploring expedition to the Pacific Ocean and the South Seas was authorized by the Congress in 1836.[9] Britain and France had already sent several successful expeditions, and the American people expected that it would be a great benefit for the country in both scientific and commercial aspects. Lieutenant Charles Wilkes, who had been the second superintendent of the Depot of Charts and Instruments, was chosen to be the commander of the expedition. In planning for the scientific work and constituting the scientific personnel, Wilkes maintained his strong preference of physical science over natural history, and naval officers over civilian scientists. Naval officers were to take charge of all the work related to "astronomy, surveying, hydrography, geography, geodesy, magnetism, meteorology, and physics." And positions for "zoology, geology and mineralogy, botany and conchology" were first

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[7] Dupree, *Science in the Federal Government*, 61-65, 105-114; Schlee, *The Edge of an Unfamiliar World*, 23-79; Manning, *U.S. Coast Survey vs. Naval Hydrographic Office*; Marc I. Pinsel, *150 Years of Service on the Seas: A Pictorial History of the U.S. Naval Oceanographic Office from 1830 to 1980*. Vol. 1 (1830-1946) (Washington, D.C.:.Department of the Navy, 1982).

[8] Schlee, *The Edge of an Unfamiliar World*, 26.

[9] Dupree, *Science in the Federal Government*, 56-65; Schlee, *The Edge of an Unfamiliar World*, 27-36. See also William Stanton, *The Great United States Exploring Expedition of 1838-1842* (Berkeley: University of California Press, 1975). For the Expedition's contribution to ethnography, see Barry A. Joyce, *The Shaping of American Ethnography: The Wilkes Exploring Expedition, 1838-1842* (Lincoln: University of Nebraska Press, 2001).

filled with the expedition's medical personnel and then with civilian scientists.[10] The expedition's ships, which left Norfolk, Virginia in August, 1838, sailed and explored many parts of the South Pacific and the Antarctic Sea until they finally arrived at New York in early 1842. Within 20 years after the return of the Expedition, more than a dozen minor naval expeditions were sent by the U.S. government.

The Exploring Expedition's scientific achievement did not have much impact, however. A large amount of collections and data were mishandled or lost in accidents. Of the remaining collections, only a few volumes of reports were published in a very protracted manner. Consequently, scientists were not generally interested in the Expedition reports as more recent, and better, results were available at the time they appeared. They could have been more influential had they been written and published in a more efficient way. Congress reluctantly supported the Exploring Expedition with the publication of the reports until 1874, but the magnificent amount of time and money spent on the project made it somewhat skeptical of supporting science.

At the Depot of Charts and Instruments, Lieutenant Matthew Fontaine Maury became the fourth superintendent in 1842, a year before Bache took office at the Survey.[11] Maury strongly felt the need for wind and current charts, perhaps from his own earlier experience of sailing aboard the *Falmouth* from the east coast to the west without any information on winds and currents when he was 25 years old. The young Maury was disappointed to find out that such crucial information was not shared and no efforts had been made to assemble the individual knowledge for common interests. He thus decided to do it as his first project at the Depot when he became the superintendent. It meant a sudden break from the previous work at the agency, which put more emphasis on astronomical observations. Maury made marine meteorology and hydrography, or the "physical geography of the sea" according to his terminology, the central mission of the Depot.

In making the wind and current chart, Maury adopted a method previously used by meteorologist William Redfield in charting the path of hurricanes in the 1820's.[12]

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[10] Schlee, *The Edge of an Unfamiliar World*, 28-29.
[11] For Maury's biography, see Frances Leigh Williams, *Matthew Fontaine Maury, Scientist of the Sea* (New Brunswick: Rutgers University Press, 1963); and Chester G. Hearn, *Tracks in the Sea: Matthew Fontaine Maury and the Mapping of the Oceans* (New York: International Marine, 2002).
[12] Schlee, *The Edge of an Unfamiliar World*, 38.

Instead of getting the information directly from the field work at sea, Maury chose to make use of the data that already existed. First, he gathered wind and current information from the logs of naval ships. Then, he distributed the so-called "abstract logs" to private ship owners where they would fill in the information from their ship logs. He promised to give them the completed chart in return for their cooperation, and this system worked very well. Without much trouble, Maury was able to compile the wind and current charts, and the first one was published in 1847. It was an immediate success as it was soon reported that the new chart saved sailors considerable amount of traveling time. Using a similar method, the Depot compiled a whale chart for whalers, too.

Encouraged by the success of the wind and current charts, Maury wanted to extend the project worldwide. He organized an International Maritime Meteorological Conference that met in Brussels, Belgium in 1853, where he proposed the use of the abstract log system in the ships of many nations. Maury's idea was favorably received. All of the ten nations represented in the conference adopted his system, and soon nine more joined. Chester G. Hearn, Maury's biographer, remarked, "This meeting was historic: never before had there been a U.S.-inspired meeting that so successfully achieved an understanding among the leading nations of the Western world." International fame and honors followed: "Four European countries knighted him, eight nations awarded him gold medals, Russia and Austria sent jeweled pins to Maury's wife, and Napoleon III made him commander of the Legion of Honor."[13]

The more his knowledge and information on the physical properties of the ocean accumulated, the more Maury felt the need to go out to the sea and make direct observations, despite the great success that he had with the abstract log method. He came to understand the necessity of direct field work at sea, which Bache's Coast Survey had already been conducting, and Maury realized that a research vessel was needed for full-scale marine explorations. In 1849, a schooner, *Taney*, was assigned to the Depot, and a few years later another vessel, *Dolphin*. With these surveying vessels, the Depot engaged in an active series of surveys in the north Atlantic Ocean, and was able to publish in 1854 the *Bathymetrical Map of the North Atlantic Basin with Contour Lines Drawn in at 1,000, 2,000, and 4,000 Fathoms*, the first contour map of the ocean basin. The next year, Maury's scientific career culminated with the publication of *The Physical*

[13] Hearn, *Tracks in the Sea*, 188.

Geography of the Sea, which contained chapters on navigation, currents, winds, weather, soundings, and fogs. With these achievements, Maury was considered an authority on the seafloor topography and was even consulted on the suitable routes for the Atlantic telegraph cable.

Since Maury had begun the scientific surveying of the seas, the mission of the Depot often overlapped with that of the Coast Survey, which quite naturally caused some trouble. Both agencies aimed at improving knowledge of the country's seafaring routes, and they did contribute to the improvement of the situation considerably. In theory, there existed a vague boundary between the domains of the Depot of Charts and Instruments and the Coast Survey. By definition, the Survey's claimed territory was the coastal seas (within 60 miles from the shoreline) whereas the Depot under Maury was more interested in the open seas. The most problematic area was the Gulf Stream, which Bache and Maury each claimed to be his agency's province. The area of strong currents, which consisted of comparably warm water, was the most conspicuous feature that every sailor could experience as he crossed the North Atlantic. The current, which Maury compared to "a river in the ocean,"[14] originates from the Gulf of Mexico and flows north to the North Pole. Understanding the Gulf Stream was crucial in securing the safety of the Atlantic navigation route to and from Europe, but its detailed cause and mechanism were not yet known to scientists or sailors. Later, in the late nineteenth century the Gulf Stream would be placed at the center of the debate on the cause of currents and oceanic circulation. It was, therefore, natural that Maury and Bache, both deeply concerned in matters of navigation and marine science, became interested in the Gulf Stream. In the end, the competition between the two agencies and their leaders resulted in better understanding of natural phenomena, which was a positive side of the story.

The rivalry and uncomfortable relationship between Bache and Maury resulted partly from their different backgrounds. Maury was a naval officer who was largely self-educated in science. His approach in the scientific matters was often quite amateurish, and even his masterpiece, *The Physical Geography of the Sea*, was generally criticized by academic men on both sides of the Atlantic for his logical mistakes and wild

[14] Matthew Fontaine Maury, *The Physical Geography of the Sea*, 6th edition (New York: Harper and Brothers, 1858), 25.

speculations. Bache, on the other hand, was a professionally trained scientist of his time who saw Maury as misplaced as the superintendent of the Depot of Charts and Instruments. For example, Bache avoided making premature interpretations of the physical phenomena of the oceans when he published the results of the Coast Survey's scientific work while Maury enjoyed making public his theories which were often amateurish. In other words, their rivalry was the best example of the animosity between the naval officers and the civilian men of science that developed during the U.S. Exploring Expedition.[15] Bache was not alone in antagonizing Maury in scientific matters. Joseph Henry, director of the Smithsonian Institution and a close friend of Bache's, also was at odds with Maury, especially in the domain of meteorological work. While Maury thought that an integrated approach to the meteorological research on land and at sea was essential and argued for a centralized national weather bureau, Henry strongly insisted that land meteorology had to be the exclusive domain of the Smithsonian Institution. Bache and Henry considered Maury a man of only practical science, and did not want to include him in their scientific circle.

Considering the generally reluctant attitude of the government in funding scientific work, it was possible only under such powerful leaders as Maury and Bache that the federal agencies, created for practical purposes, performed systematic scientific researches. They were able not only in leading scientific programs but also in dealing with the politicians. After they left office, important scientific work at both agencies weakened significantly.[16] Maury, a native of Virginia, left the Depot in 1861 when the Southern states seceded, and Bache died in 1867. The strong impetus given to American marine science by the two government agencies ceased to exist, although some scientific work still continued. Eventually, it was proven that in the nineteenth century United States government agencies fell far short of providing a permanent home for marine sciences.

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[15] Schlee, *The Edge of an Unfamiliar World*, 36.

[16] In 1866, the Depot of Charts and Instruments was renamed the Hydrographic Office. In 1878, the name Coast Survey was also changed to the Coast and Geodetic Survey. Schlee, *The Edge of an Unfamiliar World*, 63-65.

2. Early Marine Biological Stations in the United States

The scientific work done at the Coast Survey and the Depot of Charts and Instruments was generally focused on physical aspects of the sea, although some biological and geological study was done in cooperation with scholars such as Louis Agassiz. After the marine scientific work had diminished considerably at those two agencies, the tradition of American marine science was succeeded by biologists who built seaside laboratories beginning in the early 1870's.[17] It was the time when interest in marine biology boomed on both sides of the Atlantic, and many marine stations were built.

Revived interest in marine sciences in the mid-nineteenth century led to oceanic expeditions that culminated with the British *Challenger* Expedition.[18] In these expeditions, studies in natural history were almost always pursued along with physical investigations of the sea. Old and new species collected at the sea intrigued naturalists and, moreover, the discovery that life existed under the deep sea led many scientists to study marine organisms. The problem of evolution made marine biology more important. Discoveries of marine biology were used both for and against the theory of evolution. For example, naturalists found in the ocean some organisms very similar to those species that were thought to have been extinct and could be found only in fossils. This finding led some scientists such as the British Wyville Thomson to doubt the effectiveness of the evolutionary theory. On the other hand, Thomas Huxley's discovery of *Bathybius haeckelii*, which was thought to be a form of protoplasm, was believed to be a key to understanding the history of life.

Likewise, Ernst Haeckel at Jena, Germany believed that studying marine biology would yield much benefit to evolutionary biology. He had a firm belief that

[17] For general discussions on American marine biological stations, see Keith R. Benson, "Laboratories on the New England Shore: The "Somewhat Different Direction" of American Marine Biology," *The New England Quarterly*, 61 (1988): 55-78; and Benson, "Summer Camp, Seaside Station, and Marine Laboratory: Marine Biology and Its Institutional Identity," *Historical Studies in the Physical and Biological Sciences*, 32 (2001): 11-18.

[18] Deacon, *Scientists and the Sea*, 276-406; Schlee, *The Edge of an Unfamiliar World*, 107-138. See also Harold L. Burstyn, "Science and the Government in the Nineteenth century: The Challenger Expedition and Its Report," *Bulletin de l'Institut Océanographique, Monaco*, vol. 2, special no. 2 (1968): 603-611.

animals and plants living in the sea were the key to solving the problem of evolution as they were considered to be very primitive living organisms having the simplest forms of life available to researchers. He advised one of his students, Anton Dohrn, to work on marine biology, and Dohrn built a marine laboratory at Naples, Italy, following his mentor's ideas.[19] Dohrn's station, the Stazione Zoölogica was a great success and immediately became famous among biologists. It soon became a popular place where scientists from all around the world gathered to research, and among them were a number of American biologists such as Charles M. Child, Wesley R. Coe, Bashford Dean, Ross G. Harrison, Ida H. Hyde, Herbert S. Jennings, F. M. McFarland, G. H. Parker, Charles O. Whitman, T. H. Morgan, William M. Wheeler, and E. B. Wilson, to name but a few.[20]

Around the same time, marine stations began to appear in the United States. The first such attempt was by Louis Agassiz. In 1873, Agassiz opened a summer school on Penikese Island in Buzzards Bay.[21] It was not the first time that he was engaged in the marine sciences as he had had prior research work done in connection with the U.S. Coast survey and, thus, he was the right person to begin the tradition of seaside biological activities in America. The summer school was funded by a wealthy businessman named John Anderson and was often called after him the Anderson School of Natural History.

The Anderson School, which might be labeled the first American marine biology station, had distinct features that could differentiate it from its European counterparts. While the stations in Europe such as the Naples Station were strongly research-oriented, Agassiz's summer school was devoted mostly to education. For the most part, biology teachers and other amateurs interested in biology were invited to the island for the summer program, and they had chances to work in the field. As Agassiz

[19] Christiane Groeben, "Anton Dohrn—the Statesman of Darwinism," *Biological Bulletin*, 168 (Suppl.) (1985): 4-25. For the Naples Station's influence on American scientists, see Keith R. Benson, "The Naples Stazione Zoologica and Its Impact on the Emergence of American Marine Biology," *Journal of the History of Biology*, 21 (1988): 331-341; and Jane Maienschein, "First Impressions: American Biologists at Naples," *Biological Bulletin*, 168 (Suppl.) (1985): 187-191. For early European marine stations, including the Naples station, see Charles A. Kofoid, *The Biological Stations of Europe* (Washington, D.C.: Government Printing Office, 1910).

[20] Benson, "The Naples Stazione Zoologica," 335.

[21] Jane Maienschein, "Agassiz, Hyatt, Whitman, and the Birth of the Marine Biological Laboratory," *Biological Bulletin*, 168 (Suppl.) (1985): 26-34.

emphasized learning from nature and not from books, they usually collected and observed animals and plants by themselves during the day and attended Agassiz's lectures in the evening. It was a great success in the first year, but Agassiz died in the next year and the second year's session was led by his son Alexander. Thereafter, the school never opened again.

The Penikese school had a significant weakness within itself. Its whole program depended too heavily on the founder and instructor Louis Agassiz. He was an unusually talented teacher who possessed sufficient showmanship to satisfy those attending the school. His son unfortunately did not share his passion for the program for several reasons. Alexander disliked the isolated location of the island, and was more interested in advanced research in the study of marine biology than the teaching of amateurs. The school's heavily education-oriented character was often criticized, too, by others such as British scientist E. Ray Lankester. Alexander did acknowledge the value of a seaside biological laboratory, however, and built a private one at New Port, Rhode Island a few years later. This research station was one of the marine stations that Lankester highly praised.[22]

Despite the very short existence of the Penikese school, Louis Agassiz and the summer school left a lasting impact on the American marine biology movement. Agassiz had students who were no less interested in marine biology than himself, without whom the Anderson School would not have even existed. Three men, in addition to his son Alexander, were particularly important in the history of marine biology: Alpheus Hyatt, Nathaniel Southgate Shaler, and Addison Emery Verrill.[23] Shaler was in fact the original source of inspiration for the summer program in marine biology, who suggested to Agassiz that a marine station devoted to natural history and geology would be beneficial. Hyatt served as an instructor at Penikese and later became the director of a marine biology station at Annisquam. Verrill also devoted a large part of his scientific career to the study of marine biology and worked in connection with the U.S. Fish Commission from 1871 to 1887. Among those who participated in the Anderson School's program were William Keith Brooks, another student of Agassiz's, Charles O. Whitman, Cornelia

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[22] Benson, "Laboratories on the New England Shore," 65-66.

[23] Wesley R. Coe, "Addison Emery Verrill, 1839-1926," *National Academy of Sciences Biographical Memoirs*, 14 (1932): 19-66, see esp. 21-22; Benson, "Laboratories on the New England Shore," 56-58.

Clapp, and David Starr Jordan who later became leaders of several important marine stations in the United States.[24]

Another line of marine biological study began in the 1870's, led by Spencer Fullerton Baird of the Smithsonian Institution. Baird was assistant to Joseph Henry at the Smithsonian Institution, at the time he was appointed Fish Commissioner by Congress.[25] His duty was to investigate the nation's fish stock and determine the cause of declining catches. After years of field study up and down the New England coast, Baird finally settled down in 1882 in the small town of Woods Hole where he built a permanent fishery laboratory.

At the U.S. Fish Commission Laboratory, Baird was mainly expected to lead pragmatic studies for the benefit of the nation's fishing industry. However, aided by his political skills and scientific influence, Baird managed to combine applied and pure science in the investigation of fishes. The Woods Hole laboratory was open to professors and students from the institutions that possessed a right to use its facilities in return for their donations for the building of the laboratory. So, researchers from Harvard, Johns Hopkins, Princeton, and Williams came to Woods Hole during the summer to study marine organisms that could be provided by the Fish Commission. At the same time, Baird himself pursued comprehensive studies of the coastal seas with colleagues and assistants, such as Addison E. Verrill of Yale.[26] The Commission's research vessel *Albatross* brought in many new and previously known marine species from the Massachusetts coast, but Baird's interest lay not only in taxonomical study of identifying and describing the species. He and his colleagues put no less effort into tracing their life history and relating their morphology and physiology to their environment.[27] The fish

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[24] Maienschein, "Agassiz, Hyatt, and Whitman," 26-32.

[25] After Joseph Henry's death in 1878, Baird succeeded him as secretary of the Smithsonian. On Baird and the Fish Commission Laboratory, see Dean C. Allard, "The Fish Commission Laboratory and Its Influence on the Founding of the Marine Biological Laboratory," *Journal of the History of Biology*, 23 (1990): 251-270; and Philip J. Pauly, *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey* (Princeton: Princeton University Press, 2000), 44-70. For Baird's biography, see Allard, *Spencer Fullerton Baird and the U.S. Fish Commission* (New York: Arno Press, 1978); William Healey Dall, *Spencer Fullerton Baird: A Biography* (Philadelphia: J. B. Lippincott, 1915); and E. F. Rivinus and E. M. Youssef, *Spencer Baird of the Smithsonian* (Washington, D.C.: Smithsonian Institution Press, 1992).

[26] On Verrill's work at the Fish Commission, see Allard, "The Fish Commission Laboratory," 254, 258-259; and Coe, "Addison Emery Verrill," 23-25.

[27] Baird's initiative in American marine ecology is well explained in John E. Hobbie and John B.

commissioner believed that a full and comprehensive understanding of the life phenomena of the region was necessary in order to tackle the problems of the fishing industry.

The fish commission's comprehensive scientific study under Baird did not cause serious trouble with Congress, since Baird tried to balance it with practical researches more directly related to fishery studies. A large portion of the laboratory's efforts was given particularly to experiments on fish culture and artificial hatchery work. For Baird, this line of study was in fact the only possible solution to the crisis of the fishery industry given the limited knowledge of his time. The work at the Fish Commission Laboratory was geared more and more towards this direction as time went by. The advent of the Grover Cleveland administration in 1885 was a crucial event that turned the direction of the fish commission's research away from comprehensive marine science. The Democratic administration which began investigations of government agencies tried to find cases of corruption under the long Republican reigns. Baird's influence in Washington and his close relationship with politicians helped to save the research programs at the laboratory eventually, but scientific study there had to shrink afterwards. Baird's death in 1887 was a fatal blow: within a few years scientific researches at the Fish Commission was virtually eclipsed.

The case of the U.S. Fish Commission Laboratory gives another example of the federal government's failure to support long-term scientific programs. The destiny of comprehensive marine science at the laboratory rested, again, too heavily on one able leader. Following the precedents of the Coast Survey and the Depot of Charts and Instruments, the Fish Commission gradually became a narrowly focused institution for practical work.

Despite Baird's failed attempt, Woods Hole remained the center of marine biology in the United States. This was owing to the Fish Commission's new neighbor, the Marine Biological Laboratory. It was Baird himself who first suggested that the new institution be built in Woods Hole, next to his own laboratory. The Fish Commission Laboratory was essentially a research institution, devoted solely to advanced research in

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Pearce, "Ecology in Woods Hole: Baird, Bigelow, and Redfield," in Robert B. Barlow, Jr., John E. Dowling, and Gerald Weissmann, eds., *The Biological Century: Friday Evening Talks at the Marine Biological Laboratory* (Woods Hole, Mass.: The Marine Biological Laboratory, 1993), 256-286.

pure and applied sciences. Yet, Baird originally had a bigger plan. Well acquainted with Agassiz's program at Penikese, he was aware of the need for a biological institution for education. Baird hoped to expand his laboratory into a larger institution which could be a center for both research and education in marine biology.[28] As the prospect of such expansion became dim, he decided to make another attempt to build a separate institution at Woods Hole, which was the best location for the study of marine biology according to his previous experience. That new institution was the Marine Biological Laboratory. In Baird's scheme, the two neighboring stations would cooperate, not compete with each other, as they would have complementary functions of research and education.

Historians Keith Benson and Jane Maienschein have emphasized the educational function of the early American marine biological stations.[29] They have argued that the marine stations in the United States had developed in a somewhat different way than the European ones, reflecting the situation of scientific education at that time. In fact, influences from Europe on American marine biology cannot be ignored. Particularly, the Stazione Zoölogica at Naples was admired by a number of prominent American biologists who had had chances to visit and work there.[30] And some of them tried, in fact, to make it a model for American marine stations. At that time, Germany was a leader in the world of science and many leading American biologists had ties to German scientific institutions. They often visited German universities and many earned their degrees there. Those people who had some experience of spending time at Dohrn's station were deeply impressed by the pattern and style of life and work at Naples and it is not surprising that they played a significant role in founding similar ones in the United States. Yet, the Naples station and other European stations, unlike their American counterparts, were research institutions, and no educational work, such as was done at Penikese or Annisquam, was done there. Therefore, Benson and Maienschein could argue that American marine biological stations were not merely copies of the European precedents, especially the one at Naples. This distinctly American

[28] Allard, "The Fish Commission Laboratory," 266-270; Rivinus and Youssef, *Spencer Baird*, 148-149.
[29] Benson, "Laboratories on the New England Shore"; Benson, "Summer Camp, Seaside Station, and Marine Laboratory"; and Maienschein, "Agassiz, Hyatt, Whitman."
[30] Benson, "The Naples Stazione Zoologica"; Maienschein, "First Impressions."

characteristic found its full expression in the Marine Biological Laboratory at Woods Hole.

3. The Marine Biological Laboratory at Woods Hole

Alpheus Hyatt, former student of Louis Agassiz's and instructor at Penikese, founded a marine station at Annisquam, Massachusetts in 1879 with sponsorship from the Boston Society of Natural History and the Woman's Education Association of Boston.[31] He became the first director and B. H. Van Vleck, who was working as assistant for the Boston Society of Natural History, was appointed instructor. Annisquam was from the onset modeled after the Penikese school, and concentrated on education rather than original research. Most participants were school teachers. This was exactly what the two sponsor groups intended. They wanted this seaside station to be a place for educating amateurs and teachers and giving them a chance to study nature. In this respect, this school was a success, having had a number of teachers every summer, about half of them women. However, Hyatt felt that the Annisquam station had to change somehow. As the coastal sea of Annisquam became polluted by nearby industrial facilities, it needed to move to an unpolluted area. Furthermore, Hyatt wanted his station to become an institution more independent and more research-oriented. He set out to search for a new home.

It was Spencer Baird who approached Hyatt at that time with the suggestion that he move his station to Woods Hole.[32] Baird thought that there hardly existed a better place than Woods Hole as a location for marine biological stations. And Annisquam

[31] Maienschein, "Agassiz, Hyatt, Whitman," 28-29; Frank R. Lillie, *The Woods Hole Marine Biological Laboratory* (Chicago: University of Chicago Press, 1944), 26-31. It must be noted that the Annisquam station was not founded by Alpheus Hyatt alone. MIT Chemist Ellen Swallow Richards and other women at the Woman's Education Association of Boston were also active participants of the station, both as instructors and students. See Robert Clarke, *Ellen Swallow: The Woman Who Founded Ecology* (Chicago: Follett, 1973).

[32] On the natural conditions of Woods Hole, see W. D. Russel-Hunter, "The Woods Hole Laboratory Site: History and Ecology," *Biological Bulletin*, 168 (Suppl.) (1985): 197-199.

station was exactly the kind of institution that Baird wanted at Woods Hole right next to his Fish Commission Laboratory as it was almost entirely an educational marine station. The two stations would very likely benefit from each other with their complementary roles—research and education.

However, not everyone welcomed the idea of establishing another laboratory at Woods Hole.[33] For example, William Keith Brooks of Johns Hopkins was opposed to the plan. His opinion was that it was better to build the new station at another location so that biologists would have a chance to investigate more regions. Brooks, who was professor of morphology at the Department of Biology, Johns Hopkins University, already retained the right to occupy tables of the Fish Commission Laboratory. Therefore, he and his students at the Johns Hopkins could visit Woods Hole whenever they wanted. Besides the Fish Commission, he also ran his own marine station, the Chesapeake Zoological Laboratory of the Johns Hopkins University.[34] Brooks also refused Hyatt's proposal to appoint him the first director of the new marine station. Alexander Agassiz, who also had access to Baird's facilities, disagreed with the plan for a new marine biological station at Woods Hole.

Despite the minority opposition, the Marine Biological Laboratory opened at Woods Hole in 1888.[35] Hyatt, the Boston Society of Natural History, and the Woman's Education Association had their reasons to decide for Woods Hole. First, Woods Hole was the appropriate site for a marine biological station both oceanographically and geographically. Cape Cod, where Woods Hole is located, was a comparatively less polluted region on the New England coast. And as both warm and cold currents exist, biologists could study two different groups of sea organisms residing in warm and cold

[33] Maienschein, "Agassiz, Hyatt, Whitman," 29-30; Maienschein, *100 Years Exploring Life, 1888-1988: The Marine Biological Laboratory at Woods Hole* (Boston: Jones and Bartlett Publishers, 1989), 19-25, 179.

[34] Benson, "Laboratories on the New England Shore," 66-73; Philip J. Pauly, "Summer Resort and Scientific Discipline: Woods Hole and the Structure of American Biology, 1882-1925," in Ronald Rainger, Keith R. Benson, and Jane Maienschein, eds., *The American Development of Biology* (New Brunswick: Rutgers University Press, 1988), 121-150. See esp. 125-126.

[35] For general accounts of the MBL's early history, see Lillie, *The Woods Hole Marine Biological Laboratory*; Maienschein, *100 Years Exploring Life*; Maienschein, ed., *Defining Biology: Lectures from the 1890s* (Cambridge, Mass.: Harvard University Press, 1986); Pauly, "Summer Resort and Scientific Discipline"; Detlev W. Bronk, "Marine Biological Laboratory: Origins and Patrons," *Science*, 189 (1975): 613-617; and articles in *Biological Bulletin*, 168 (Suppl.) (1985).

currents, respectively.[36] Moreover, Woods Hole had convenient means of transportation. Since some factories had been built near the town some time before, a railroad connecting Boston and Woods Hole was available. It did not take much time to travel from Boston to Woods Hole by train. Second, existence of the Fish Commission Laboratory at Woods Hole did not seem to be a real problem to the Boston Society and the Women's Association as they too, like Baird, believed in the division of roles between the two institutions. Unlike Hyatt, those sponsors wanted the MBL to remain an educational institution. They had every reason to welcome the existence of the Fish Commission which would possibly provide the MBL with facilities and even instructors. Baird himself had promised to give the needed land at a cheap price and let MBL use the facilities of his laboratory, and it was quite an attractive offer. The new station would not have to pay additional expenditures for such things as waterworks and expensive instruments, which meant for the sponsor groups saving much money.

The plan to make the new MBL an educational institution soon met with a serious challenge. The conflict first arose in the process of selecting the first director.[37] The trustees of the MBL were divided between scientists, of whom Hyatt was the leader, and the people from the Boston Society of Natural History and the Woman's Education Association of Boston. While the trustees who had ties to the Boston Society and the Woman's Association hoped to maintain the education-oriented tradition of Annisquam, Hyatt and the scientist-trustees wanted to bring a substantial change to its character. The amateur members recommended van Vleck of the Boston Society, but the scientists wanted a prominent scholar such as Brooks to lead the MBL and make it a research institution. The scientists' opinion dominated and, at last, Charles Otis Whitman was selected as the director after Brooks refused the offer.

Whitman had participated in Agassiz's Penikese school and decided to pursue a career as a professional scientist.[38] When he was a 31 year-old high school teacher, he

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[36] Russel-Hunter, "The Woods Hole Laboratory Site."

[37] Maienschein, *100 Years Exploring Life*, 19-25; Maienschein, "Early Struggles at the Marine Biological Laboratory over Mission and Money," *Biological Bulletin*, 168 (Suppl.) (1985): 192-196.

[38] On Whitman's life and career, see Ernst Mayr, "Charles Otis Whitman," in Charles C. Gillispie, ed., *Dictionary of Scientific Biography*, Vol. XIV (New York: Scribner, 1976), 313-315; Maienschein, "Introduction," in *Defining Biology*, 3-50; Pauly, "Summer Resort and Scientific Discipline," 129-130; and Maienschein, "Physiology, Biology, and the Advent of

went to Europe to study biology. He went to Leipzig to study with Rudolf Leuckart after a visit to Dohrn's Stazione Zoologica at Naples. Whitman received his doctoral degree in zoology in 1878 and, then, worked two more years at Naples. Unable to find a job in the United States, Whitman went to Japan where he became professor of biology at Tokyo Imperial University. Two years later, he returned to America and was employed privately by Alexander Agassiz at Harvard's Museum of Comparative Zoology and, then, by a rich amateur zoologist of Milwaukee, E. P. Allis, Jr. His experience of directing the Allis Lake Laboratory was considered when the MBL trustees chose him. There Whitman founded the *Journal of Morphology* with the support of Allis. A year after accepting the MBL directorship, he was appointed at the new Clark University as a faculty member and, in 1892, moved to the University of Chicago where he remained until his death in 1910.

By the time Whitman was finally appointed the first director of the MBL, therefore, he had gone through a difficult career path and had experience of working at several biological institutions. It was natural for him, then, to be quite ambitious for the future of MBL. He intended MBL to be "one of the strongest and most productive biological stations in the world."[39] Such a grand goal inevitably led Whitman to emphasize research and expansion of the Laboratory. Whitman's leadership soon caused trouble with the MBL trustees. It was not what the amateur trustees wanted MBL to be. Their idea of the MBL was something not so different from the Annisquam station, both in size and in function. Their disagreement was intensified by financial deficiency. In 1896, for example, Whitman proposed to build a fifth building for the MBL. From the Trustees' point of view it was absolutely impossible. But the building was built, and the MBL had to face a severe financial crisis.[40]

From the beginning, Whitman himself was aware of the shortage of funds. He made every effort to secure sufficient financial support to maintain his plan. He almost succeeded twice. In 1895, Miss Helen Culver, a rich woman of Chicago, told Whitman

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Physiological Morphology," in Gerald L. Geison, ed., *Physiology in the American Context: 1850-1940* (Bethesda: American Physiological Society, 1987), 177-193.

[39] Maienschein, "Early Struggles," 193.

[40] On the MBL's financial crisis and Whitman's efforts, see Lillie, *The Woods Hole Marine Biological Laboratory*, 34-62; Maienschein, "Early Struggles"; Maienschein, *100 Years Exploring Life*, 49-72; Pauly, "Summer Resort and Scientific Discipline," 130-142; and Bronk, "Marine Biological Laboratory."

that she wanted to contribute 500 thousand dollars each to the MBL and the biology program of the University of Chicago, where Whitman was the chair. In the end, however, all of her contribution went to the University of Chicago and none was given to the MBL, much to Whitman's disappointment. In 1896, during the controversy over Whitman's policy of expansion, the amateur trustees of MBL from Boston retired from the management of the Laboratory.[41] And now the issue was not whether to allow the expansion or not but how to support the expansion. Whitman did not have to consume his energy in quarrelling with the non-scientific people any more, but the financial situation of the MBL did not improve. Once again, the helping hand came from Chicago in 1901, when four businessmen of Chicago presented to W. R. Harper, who was the president of the University of Chicago, their intention to contribute to the MBL. The MBL trustees decided to refuse it, although Whitman was eager to secure the funds. The trustees, who were now comprised of only scientists, were afraid that the influence of the University of Chicago in the MBL might be too strong. Whitman was greatly depressed at this decision.

Whitman's position was reversed in the events of the next year.[42] The MBL trustees tried to get financial support from the Carnegie Institution of Washington. Henry Fairfield Osborn, who was president of the MBL corporation, and Edmund Beecher Wilson, the chairman of the executive committee, were the leaders in this movement. Osborn was the chairman of the Carnegie Institution's Committee on Zoology, and Wilson was also a member of this committee along with Alexander Agassiz, W. K. Brooks, and C. Hart Merriam. They believed that the support from the Carnegie Institution would permanently relieve the MBL's financial difficulties, and to this Whitman did not object. Wilson and Osborn wrote to the other MBL trustees:

> If the Laboratory is placed under the control of the Carnegie Institution, its future is assured on a splendid and permanent basis. We would have the opportunity to develop the Laboratory into one of the highest rank and to render

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[41] Maienschein, "Early Struggles," 193-194; Pauly, "Summer Resort and Scientific Discipline," 132.

[42] Bronk, "Marine Biological Laboratory," 614-615; James D. Ebert, "Carnegie Institution of Washington and Marine Biology: Naples, Woods Hole, and Tortugas," *Biological Bulletin*, 168 (Suppl.) (1985): 172-182; Maienschein, "Early Struggles," 195-196.

> a great and lasting service to the cause of American science.[43]

What caused Whitman to change his mind and to object to this plan eventually was the fact, as implied in the above passage, that it demanded MBL's absorption into the Carnegie Institution, to become just one of its many branches. It resulted from the policy that the Carnegie Institution had to "be an operating, not a granting institution." It had to "carry on its own work, under its own name, and should publish the results in its own series of publications." Whitman could not allow the MBL's incorporation into the Carnegie Institution in spite of its financial merits, as it would inevitably destroy MBL's independence.

'Independence' was, as Jane Maienschein pointed out, one of the keywords in understanding Whitman's directorship at MBL.[44] He had stressed that the MBL had to be a national, public institution managed by the scientists working at the Laboratory without any interference from outside. He firmly believed that that was the only way to maintain the free spirit of scientific investigation at the MBL. For example, Whitman had written to Helen Culver that

> The Marine Biological Laboratory had already become an intercollegiate centre for research and instruction. Some over twenty colleges and universities are now contributing to the support of the Laboratory by subscriptions to rooms and tables, and no less than eighty-five institutions were represented in our membership last summer. The national character of the Laboratory is the chief glory and that I am sure will be wisely guarded in the foundation you have bestowed.[45]

To Whitman, therefore, the Carnegie plan was a serious threat to his ideal, which endangered the MBL's independence. Whitman was strongly opposed to Wilson and Osborn's proposal even though he had but a few supporters, including Edwin Grant Conklin and Frank Lillie. The majority of the MBL trustees were on the other side. He

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[43] Bronk, "Marine Biological Laboratory," 614.
[44] Maienschein, *Defining Biology*, 17-21; Charles O. Whitman, "The Impending Crisis in the History of the Marine Biological Laboratory," *Science*, 16 (1902): 529-533.
[45] Maienschein, "Early Struggles," 193.

publicly promoted the importance of MBL's independence on the pages of *Science* magazine and, finally, succeeded in annulling the incorporation.[46] Instead, the MBL trustees accepted the Carnegie Institution's generous offer to grant 80,000 dollars for buying MBL's new facilities, and another 10,000 dollars each year for the next three years.[47]

Whitman succeeded in defending MBL's independence, but he became exhausted. He soon decided to retire from the MBL directorship, and was succeeded by his former student and colleague Frank Rattray Lillie. Lillie later expanded the MBL even more with the aid of his brother-in-law Charles R. Crane. Lillie could also get support from the Rockefeller Foundation through the National Research Council.[48]

With his clear vision, Whitman thus managed to overcome the financial difficulties and succeeded in making the MBL a major research institution. By the end of the nineteenth century, it became one of the centers of biological investigation in the United States. In particular, MBL was the headquarters of cell lineage study, and researches in embryology, cytology, and physiology flourished there.[49] Emphasis on research was not the only way in which the MBL differed from the previous Annisquam station, however. The style of doing biology changed as well. Marine biology at the MBL was very different from the natural history done at Penikese, Salem, Annisquam, and the Fish Commission Laboratory. The MBL biologists put more and more emphasis on laboratory work and spent less time collecting and observing animals and plants at sea. They were seeing their organisms through microscopes inside the laboratory and did not care about the living conditions of those animals they worked with. Where and how the marine organisms lived simply did not matter to them. Some of the active members of the MBL did mention the need to study elsewhere and a few did in fact spend summers at other American seaside stations and in Naples. But they did so not because they were interested in different marine environments but because they wanted to try

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[46] Whitman, "The Impending Crisis."
[47] Bronk, "Marine Biological Laboratory," 614; Ebert, "Carnegie Institution of Washington," 174-180.
[48] Bronk, "Marine Biological Laboratory," 615-617; Maienschein, *100 Years Exploring Life*, 70-71; Lillie, *The Woods Hole Marine Biological Laboratory*, 63-84.
[49] For the early scientific work at the MBL, see Maienschein, *Defining Biology*, 3-50; Maienschein, *100 Years Exploring Life*, 93-99, 117-150; Lillie, *The Woods Hole Marine Biological Laboratory*, 115-156; and Benson, "The Naples Stazione Zoologica."

their theory with the species not found at Woods Hole. MBL thus broke from the natural history tradition in marine biology, yet the tradition of natural history did survive at other, smaller marine biological stations throughout the coasts of the United States.

4. Controversy over the Tortugas Marine Biological Station: An Example of the Small-Sized Marine Biological Stations

In many coastal regions of the United States, other marine stations appeared in the 1890's and 1900's. In January 1903, Alfred Goldsborough Mayer at the Museum of the Brooklyn Institute of Arts and Sciences proposed a plan for yet another marine biological station in the tropical Atlantic region.[50] Having had considerable experience of working at different places, Mayer knew quite well the advantages and disadvantages of possible marine station sites, and his choice was the Tortugas in Florida. He reported that extremely rich tropical marine fauna could easily be found in the region, which had not been carefully studied until that time except by some "cursory visits of the United States government expeditions in the *Bibb*, 1869; *Blake*, 1877-78, and *Albatross*, 1885-86," and by "the explorations of Louis Agassiz, 1850-51, and Alexander Agassiz, 1881."[51] In more recent years, non-governmental expeditions were conducted by the University of Iowa led by C. C. Nutting in 1893, and by the Museum of the Brooklyn Institute of Arts and Sciences in 1902 where Mayer himself participated. Having emphasized the natural advantages of the Tortugas and the insufficient amount of biological research done there, Mayer argued for the need to build a permanent station. He concluded that

> The time has come when American men of science should awaken to the fact that we have at our very door a tropical fauna far surpassing in richness that of Naples. With our great wealth and many able and

[50] Alfred Goldsborough Mayer, "The Tortugas, Florida, as a Station for Research in Biology," *Science*, 17 (January 30, 1903): 190-192.
[51] Ibid., 190.

> energetic workers, we should begin to perform the task for science which is being so ably done at Naples. The great monographs of the Naples Laboratory should be our incentive to do even more and better things in the development of knowledge concerning the marine life of tropical America.[52]

Mayer lamented that "we know more of the life of the Red Sea than we do of that of the Caribbean and Gulf of Mexico."[53] American biologists read and knew very well the results of their European colleagues' researches, and they themselves often went to Naples and other parts of Europe to study biology of those regions. But until that time only a meager amount of study had been done on the marine fauna and flora of the new world, and the tropical region on the east coast was certainly one of those unexplored places. Mayer explained that the "cause of this neglect has been that none of our educational institutions has been able to afford to maintain a permanent laboratory in the tropics, and no cooperation has yet been, or is likely to be, effected which could bring such a laboratory into being."[54] At that time, there was no academic institution in the region which could carry out long-term biological surveys, and this distant and isolated location prevented major American institutions from establishing a permanent biological station there.

Mayer thought that the situation could somehow change with the establishment of the Carnegie Institution of Washington. It seemed that this new institution would be a strong supporter of scientific research, and Mayer thought that his idea of building a marine biological station at the Tortugas was a perfect project that the Carnegie Institution would be willing to support. His proposed station would cost 6,000 dollars for the construction of a "well-ventilated wooden laboratory building capable of accommodating from six to twelve investigators" and its accessory buildings alone, Mayer estimated, and there had not been a possible source of such a large amount of money before the advent of the Carnegie Institution. In addition to the buildings, he wanted the station to have a "seaworthy launch at least 55 feet in length and of light

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[52] Ibid., 192.
[53] A. G. Mayer, "A Tropical Marine Laboratory for Research?" *Science*, 17 (April 24, 1903): 655-660. For this quotation, see p. 655.
[54] Ibid., 655.

draft" provided with "sails, auxiliary naphtha for power, and sounding and dredging reels" which would enable the "study of the life of the Gulf Stream . . . and of numerous reefs at the Tortugas and its neighborhood."[55]

In order to submit the proposal to the Carnegie Institution, Mayer had to make sure that its usefulness for science was strongly backed by a wide consensus of opinion among leading scientists of the country. He argued that the station had to be "national in character" and "meet with the entire approbation of our leading naturalists," and "be visited by an able and numerous clientage." He sent out letters asking for opinions first to "leading zoologists of the United States and Canada," and later to marine botanists as well.[56] In the *Science* article of April 24, 1903, Mayer reported that he received replies from 43 zoologists: "M. A. Bigelow, Chapman, Conklin, Dall, Davenport, Dean, Dodge, Edwards, Evermann, Gill, Hargitt, Herrick, L. O. Howard, Jennings, H. P. Johnson, D. S. Jordan, V. L. Kellogg, Kingsley, Lillie, Lucas, MacBride, McMurrich, Metcalf, Mills, Minot, Montgomery, Morgan, Neal, Nutting, Ortmann, G. H. Parker, Rathbun, Ritter, Sedgwick, Springer, R. M. Strong, Treadwell, Verrill, H. B. Ward and four others whose names we are not at liberty to reveal." All of these zoologists agreed on the need for a tropical marine station even though there was some disagreement upon the exact location.[57] Jamaica, the Bermudas, the Bahamas, Puerto Rico, and Miami were among the alternative places proposed by some.

Why, then, did so many biologists unanimously express their approval of this

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[55] Mayer, "The Tortugas, Florida," 191-192.
[56] Mayer, "A Tropical Marine Laboratory," 656.
[57] Ibid., 656-660. This article contains letters from Frank M. Chapman, Charles B. Davenport, Bashford Dean, Frank R. Lillie, C. C. Nutting, Henry B. Ward, E. G. Conklin, Francis H. Herrick, Herbert P. Johnson, A. E. Verrill, and T. H. Morgan. See also, "The Proposed Biological Laboratory at the Tortugas," by C. C. Nutting, Wm. E. Ritter, and David S. Jordan, *Science*, 17 (May 22, 1903): 823-826; J. E. Duerden, "A Tropical Marine Laboratory for Research," *Science*, 17 (May 29, 1903): 862-864; E. W. MacBride, "The Proposed Biological Laboratory at the Tortugas," *Science*, 17 (June 5, 1903): 909-910; "The Proposed Biological Laboratory at the Tortugas," by C. B. Davenport, Robert Payne Bigelow, and B. W. Barton, *Science*, 17 (June 12, 1903): 945-947; Hubert Lyman Clark, "The Proposed Biological Laboratory at the Tortugas," *Science*, 17 (June 19, 1903): 979-980; "The Proposed Biological Laboratory at the Tortugas," by P. H. Rolfs and J. Fred. Clarke, *Science*, 17 (June 26, 1903): 1008-1010; "The Proposed Biological Laboratory at the Tortugas," by Conway MacMillan and Herbert M. Richards, *Science*, 18 (July 10, 1903): 57-58; R. T. Colburn, "The Proposed Biological Laboratory at the Tortugas," *Science*, 18 (July 17, 1903): 86-87; and Mayer, "The Bahamas vs. Tortugas as a Station for Research in Marine Zoology," *Science*, 18 (September 18, 1903): 369-371.

plan of building another marine biological station when there already existed several such stations, especially the most popular Marine Biological Laboratory at Woods Hole? Charles B. Davenport, one of Mayer's correspondents and a strong supporter, explained the situation well in his letter dated June 12, 1903.[58]

> In the marine biological stations (which carry on, it must be remembered, only a portion of all biological work) two tendencies, opposite at first sight, but really directed toward the same high aims, are discernible. The one tendency is to investigate the phenomena of structure, development and function in the individual; the other is to consider individuals in masses as species, as form-units bearing the imprint of environment, and adapted thereto, and as constituents of faunas. For students of the first sort of marine zoology what is required is one large central laboratory, with an extensive library and the requisite cytological and physiological apparatus, where students of anatomy, embryology and physiology may work together and give mutual aid and stimulus. The needs of the workers on the other side of marine zoology call for several laboratories, widely separated, in diverse environments. These will assist the first sort of laboratory by furnishing particular kinds of material found only in the locality. But their chief work will be to study the fauna, determining the laws of geographic distribution of organisms, the variation of species in different environments and the interaction of organisms. Such laboratories will, of course, be exclusively for research, and should be equipped with everything requisite for the collection, the study alive and the rearing of organisms.[59]

Davenport then mentioned Woods Hole's MBL as the representative of the first kind of marine stations. At the same time, it was obvious where Mayer's proposed station would belong. Despite his contention that the Tortugas station would also serve the researchers

58 Davenport, "The Proposed Biological Station," 945-946.
59 Ibid., 945.

of physiology and embryology, it was obvious to everyone concerned that it would be primarily a station for field biologists.

Davenport went on to articulate more about the idea of the "several laboratories, widely separated, in diverse environments."[60] He mentioned "a magnificent chain of biological stations" in Europe "reaching from Tromsö, Norway, and even the White Sea, along the North Atlantic, the Baltic and North seas, the Irish Sea, the Channel, the Bay of Biscay, and the Mediterranean, Adriatic and Black seas." The European stations forming the chain were founded and run by "individual enterprise[s] or universit[ies] backed by government support." The American biologists, too, Davenport wrote, were "planning a chain of marine stations." He named those American marine stations that already existed, including "the Woods Holl Laboratory."[61] On the east coast there were a series of stations at Harpswell, Woods Holl, Cold Spring Harbor, Beaufort and Bermuda. And on the west coast, there were the Hopkins Laboratory and the University of California's marine station. To this list Conway MacMillan added the Minnesota Seaside Station at Port Renfrew, British Columbia.[62] This station, although located in Canada, was "managed in connection with one of the American Universities and [had] drawn its clientele principally from the western United States." In this respect, MacMillan argued that it also had to be considered "one of the Pacific coast stations of America" and that Davenport had had to include it in his list of the marine biological stations of the U.S. biologists. In order to complete the chain, Davenport wrote about the possibility of establishing more stations at Jamaica, Porto Rico, the island of Grand Manan or the coast of Newfoundland, and Puget Sound; and of "exploring in successive years the fauna of Davis Strait, Hudson Bay, Bering Sea and the Gulf of California."[63]

In the United States, the situation was less favorable than in Europe as, without substantial governmental support for marine biology, except the case of the Fish Commission, the establishment of such marine stations had been impossible at places far

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[60] Ibid., 945-947.

[61] The spelling of Woods Hole varied, and at this time both "Woods Holl" and "Woods Hole" were used. Pauly, "Summer Resort and Scientific Discipline," 145, n. 24.

[62] MacMillan, "The Proposed Biological Station." For a general account of the marine biology on the west coast of the United States, see Keith R. Benson, "Marine Biology or Oceanography: Early American Developments in Marine Science on the West Coast," in Keith R. Benson and Philip F. Rehbok, eds., *Oceanographic History: The Pacific and Beyond* (Seattle: University of Washington Press, 2002), 298-302.

[63] Davenport, "The Proposed Biological Station," 946.

away from major university centers. Only those universities, which had been slowly becoming research institutions, were able to run their own marine biological stations. On the tropical Atlantic coast, there was no such research university at the time and American biologists could not afford to have a permanent station there until the emergence of the Carnegie Institution had given them the hope. Alfred Mayer quickly noticed the chance, and all the biologists that he consulted supported his plan. It was the time when C. O. Whitman struggled to defend the MBL's independence from the Carnegie Institution plan of incorporation. In fact, MBL was Carnegie's first consideration, though the incorporation of MBL into Carnegie did not happen in the end. The Carnegie Institution favorably accepted Mayer's proposal and, in 1904, the Marine Biological Laboratory at the Dry Tortugas, Florida was established.[64] The Dry Tortugas Laboratory of Mayer constituted, with Davenport's Station for Experimental Evolution at Cold Spring Harbor, New York, the Carnegie Institution's biology program. Later, the Station for Experimental Evolution merged with the Eugenics Record Office to form the Department of Genetics. The Dry Tortugas Laboratory was, however, not a mere alternative to the MBL as it had been included in the Carnegie Institution's initial plan. The Committee on Zoology had strongly advocated in its report "the establishment of a permanent biological laboratory as a central station for marine biology in general, with branches at such other points as may seem desirable; also affiliated or independent experimental stations for the study of physiological zoology and problems relating to heredity, evolution, etc."[65] The members of the committee had certainly had the MBL in mind when they mentioned the "central station," while the Tortugas fit well into the "branches at such other points."

Mayer, who was just 36 years old at that time, was an able man very suitable for the job. He had grown up in a scientific family and, having been trained under Alexander Agassiz at the Museum of Comparative Zoology and having worked as a curator at the Brooklyn Institute of Arts and Sciences, he had already built a strong career as a scientist.[66] He spent summer months at Dry Tortugas often sailing on the laboratory's

[64] Ebert, "Carnegie Institution of Washington," 180-182; Patrick L. Colin, "A Brief History of the Tortugas Marine Laboratory and the Department of Marine Biology, Carnegie Institution of Washington," in Mary Sears and Daniel Merriman, eds., *Oceanography: The Past* (New York: Springer-Verlag, 1980), 138-147.
[65] Ebert, "Carnegie Institution of Washington," 173.
[66] C. B. Davenport, "Alfred Goldsborough Mayor," *National Academy of Sciences Biographical*

yachts *Physalia* and *Anton Dohrn*, and during the rest of the year he went on expeditions to various regions of the Pacific and Atlantic Oceans. He worked on a wide range of biological topics, from coral reef studies to physiological experiments on marine animals. Visiting researchers also did important work at the Dry Tortugas Laboratory. They included L. R. Cary, E. G. Conklin, H. S. Jennings, William K. Brooks, R. P. Cowles, Jacob Reighard, U. Dahlgren, R. A. Daly, C. H. Edmondson, E. N. Harvey, W. H. Longley, D. H. Tennent, and T. W. Vaughan. It is reported that around 146 different investigators worked at the station from 1905 to 1939.[67]

Mayer began to have difficult times in 1918 when the Laboratory had to close because of the First World War. His family name caused unbearable trouble to him during the war, which eventually led to his decision to change the family name from the German 'Mayer' to English 'Mayor.'[68] The laboratory opened in 1919 but had to be closed again in 1920 because of a severe hurricane that seriously damaged the station's facilities. Mayer soon had tuberculosis after an expedition to the Pacific and had to spend some time in a sanatorium. He returned to Tortugas in 1922 in spite of his doctor's warning, and on June 24 was drowned while bathing in shallow water. Mayer was succeeded by William H. Longley of Goucher College, yet not as director but as administrative officer as the Carnegie Institution did not want to continue its Department of Marine Biology in the same way.[69] Longley died in 1937, and David Tennent of Bryn Mawr College worked as executive officer until 1939 when the laboratory finally closed by the decision of the Carnegie's new president, Vannevar Bush. The station's equipment

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Memoirs, 21 (1926): 1-10; Davenport, "The Researches of Alfred Goldsborough Mayor," *Science*, 56 (1922): 134-135; Colin, "A Brief History of the Tortugas Marine Laboratory"; Ebert, "Carnegie Institution of Washington," 180-182.

[67] On the scientific work done at the Tortugas Laboratory, see Colin, "A Brief History of the Tortugas Marine Laboratory"; J. S. Kingsley, "Papers from the Tortugas Laboratory," *Science*, 30 (1909): 368-369; Davenport, "The Researches of Alfred Goldsborough Mayor"; A. A. Schaeffer, "Research at the Tortugas Laboratory," *Science*, 56 (1922): 468-470.

[68] Here, I will use 'Mayer' throughout for the sake of consistency.

[69] Colin, "A Brief History of the Tortugas Marine Laboratory,"143-145; Ebert, "Carnegie Institution of Washington," 182. For examples of the discussion on the fate of the laboratory after Mayer's death, see Davenport, "The Researches of Alfred Goldsborough Mayor"; Schaeffer, "Research at the Tortugas Laboratory"; W. J. Crozier, "Research in Marine Biology," *Science*, 56 (1922): 751-752; Crozier, "Marine Zoological Stations," *Science*, 57 (1923): 498-499; W. K. Fisher, "Research in Marine Biology," *Science*, 57 (1923): 233-235; W. E. Allen, "A Program of Oceanic Investigations," *Science*, 57 (1923): 499-500; and A. A. Schaeffer, "The Marine Laboratory at Tortugas," *Science*, 58 (1923): 160-161.

went to the Smithsonian Institution at Washington, and the *Anton Dohrn* was donated to the Woods Hole Oceanographic Institution.

Despite the considerable scientific contributions produced at the Dry Tortugas Laboratory, it turned out that Mayer's selection of location had not been perfectly appropriate. There had been some reasonable opposition to Dry Tortugas from the beginning.[70] Among the scientists Mayer consulted, some people favored Jamaica and others preferred the Bermudas, for example, as a better location for a subtropical marine station. There were two reasons for their distaste for Tortugas. On the scientific side, Tortugas did not offer chances to study land biology despite its ideal conditions for the study of marine biology. Some visitors would want to investigate the local animals and plants on land, or perhaps the geology of the region, in their spare time while staying at the station. The other, probably the more important, reason for the opposition was Tortugas' unfavorable living conditions. Most such problems were caused by Tortugas' isolated location. Even though Mayer tried his best to assure his colleagues that their concerns were groundless, they still had doubts.[71] They pointed out, first, that transportation to Dry Tortugas was extremely inconvenient. It took a long time, and much money, to get there from many academic centers of the country, and once they arrived at the Tortugas they would have to stay isolated from civilization as it was very difficult to make short visits to nearby towns. Visiting scientists could thus hardly expect their families to accompany them to the Tortugas. Some people even worried about the possibility of tropical diseases. Living conditions certainly were an important factor, since many of the visiting researchers would have to stay there for several months. Tortugas could offer almost nothing to them during the time of each day when they were out of work. It should also be remembered that work was not the only thing American biologists had in mind when they visited marine biological stations during summer. As Philip Pauly rightly pointed out, marine stations were "summer resorts" for American biologists of that time.[72] It is understandable that they did not want a summer resort at a place like the Dry Tortugas.

In the end, Mayer managed to silence this opposition, and the Tortugas marine station was established as a part of the great chain of stations. Yet, it did not take long for

[70] See the *Science* articles mentioned in n. 56.
[71] Mayer, "The Bahamas vs. Tortugas."
[72] Pauly, "Summer Resort and Scientific Discipline."

everyone to realize that the problems were real. The most serious trouble was the recurring hurricanes. Every year the hurricane season in the region seriously shortened the period of the station's operation. Moreover, some hurricanes were so powerful as to even destroy the laboratory facilities, as was the case in 1919. Even Mayer came to consider the moving of the laboratory to another region because of the problematic location of Dry Tortugas, when he thought enough work had been done there. Officials of the Carnegie Institution were also aware of the problems, which led to their decision to not continue the laboratory at the same scale as before when Mayer died in 1922.

Despite the final closure of the station at Dry Tortugas in 1939, marine biology, or marine sciences more generally, did not cease in Florida. In 1943, F. G. Walton Smith of the University of Miami at Belle Isle, Florida opened the Miami Marine Laboratory.[73] Since Smith had learned from the experience of the Tortugas Laboratory, it was built at an easily accessible place. Unlike Tortugas, this university-based station continued to operate well and grew into a major center of marine science. The magnificent American chain of marine stations, therefore, did not lose its branch in Florida in the end.

5. Conclusion: A New Direction in the Historical Study of American Marine Stations

The science of the sea began as a government activity in the United States. Its fate depended on the capricious decisions of the congress which was often reluctant to provide governmental scientific programs with steady financial support. Therefore, those scientific projects undertaken under the auspice of the federal government always had to have practical aims. They were often very successful, and the work done at the Coast Survey and the Depot of Charts and Instruments was very highly rated even by European experts. Those high-level scientific investigations could not be steadily pursued, however, because of politics. In this respect, the American marine biological

[73] Thomas Barbour, "Marine Biological Laboratories," *Science*, 98 (1943): 141-143; F. G. Walton Smith, "Functions and Development of a Tropical Marine Laboratory," *Science*, 103 (1946): 609-611.

stations that began to emerge in the late nineteenth century were noteworthy as they came to provide, for marine scientists, more stable institutional settings sufficiently apart from political fluctuations.

Historians of science have paid considerable attention to the American marine biological stations, mostly with emphasis on their role in the development of American biology. They have tended to focus disproportionately on the Marine Biological Laboratory at Woods Hole. MBL certainly was the largest, most popular and, probably, most successful marine station, and the one which no doubt has occupied the most influential place in the history of American biology. Morphological and physiological study done at laboratories of the MBL became the dominant methodology of biology throughout the country. The combined focus of embryology, cytology, genetics and evolution shaped the main research problems for the younger-generation researchers. Moreover, the summer community of biological scientists gathered from all around the country brought about the formation of a social network and a professional identity among generations of American biologists. In short, it may not be an exaggeration to claim that without the MBL American biology would have looked quite different.

MBL was by no means an isolated phenomenon, however, as it was a part of the great chain of American marine stations. It is important to see, first, the whole picture instead of paying too much attention to just one or two major marine stations. MBL did not represent all the American biologists at the time. A number of biological scientists who belonged to the older tradition of natural history were also studying marine biology in different ways at other, usually smaller, marine stations throughout the coasts of the United States at the same time. In most cases, these marine biologists, unlike their colleagues at the MBL, emphasized field work, and they believed that comprehensive understanding of the marine organisms and their living conditions in their natural habitats were indispensable for the true science of biology. These field-oriented biologists usually had critical attitudes toward the MBL-style marine biology done at laboratories without much attention to where and how those animals and plants lived in the sea. The more or less naturalistic marine biology at the smaller marine stations by no means remained stagnant. Those researchers of marine biology tried various new methodologies and studied diverse aspects of the phenomena of marine life. It is, therefore, wrong to see the history of marine biology as a linear development from natural history of the sea to laboratory biology that used marine organisms to tackle important biological problems of the day. Marine biology was developing into several different directions, and the MBL represented only one of these. Only by looking at both sides of American marine biology would we be able to get the full picture. Presenting MBL as the representative model of American marine biological stations would inevitably lead to a distorted understanding of the history of American biology of this period.

Another tendency of the current historiography of American marine biological stations is to emphasize their educational function as a distinctive characteristic of the American marine biology tradition as opposed to the European. Keith Benson, for example, pointed out that "American biologists confronted a problem much different from Dohrn's. Whereas he recognized an opportunity to provide an additional research facility for professional researchers, Americans found a need to train researchers when they had no facilities."[74] The emphasis on the educational function of the marine stations, thus, reflected the unique situation of American science. Jane Maienschein also stressed this point and argued that the American marine biological stations, including MBL, were not mere replicas of the Naples zoological station.[75] She showed how the American tradition was begun at Penikese, transmitted to Alpheus Packard's Salem station and Annisquam, and finally reached the MBL. Despite Whitman's strong drive towards research, MBL remained for long an institution devoted to both education and research.

What this historiography has neglected is the fact that the other marine biological stations that formed the majority of the chain did not have much room for education of teachers and amateurs. Many of these stations were connected to universities, and they were devoted primarily to research. Education of graduate and undergraduate students who worked there was done through research. These stations usually had a strong leader, often director or professor, who led a group of researchers and students working on carefully planned research areas. For example, William K. Brooks of the Chesapeake Laboratory and William E. Ritter of the University of California's marine biological station fit well into this category; Spencer Baird at the Fish Commission Laboratory, Alexander Agassiz at his own New Port station, and

[74] Benson, "Summer Camp, Seaside Station, and Marine Laboratory," 14.
[75] Maienschein, "Agassiz, Hyatt, Whitman."

Alfred Mayer of the Carnegie Institution's Dry Tortugas Laboratory may also be mentioned as leaders of research-oriented marine stations even though their stations were not affiliated with universities. Visitors to these stations were also coming for research.

The smaller stations that constituted the chain become even more important if we see the place of the marine biological stations within the historiography of marine sciences in general, or of oceanography in particular. Although all the American stations began as marine biological stations, these stations had some room for scientific fields other than marine biology. At the MBL, on the other hand, interest in the sea itself and ecology diminished soon after its establishment and laboratory biological work prevailed.[76] For example, William Libby of Princeton University, who had worked at the Fish Commission, gave a lecture at MBL titled "The Study of Ocean Temperatures and Currents" in 1890 and another, titled "The Physical Geography of the Sea," in 1892.[77] He was the only person who lectured on the physical sciences of the sea, and after him no lecture at MBL dealt with non-biological aspects of the ocean. Biometry and quantitative method in biology were not welcome at the MBL, either. Davenport once had a chance to lecture on this method in the study of variation, but he himself did not find MBL a good place to do research in that direction. Such diverse approaches could be tried at other seaside stations, however.

It was much easier at the small marine stations to change the direction of research when necessary. Their small size and strong leadership made such a shift comparatively easy. When a station turned out to be inappropriately situated at a certain time, a decision could be made to close it, as was the case with Agassiz's New Port Laboratory and the Dry Tortugas Laboratory, or to move it to another, more desirable, place. Some stations shifted their main field of study from marine biology to other scientific fields. A few turned to oceanography. In California, William Ritter had been aware of the need for knowledge of physical properties of the sea, and had a physical scientist accompany him whenever he led seaside investigations from very early times. In the 1920's, his station, the Scripps Institution of the University of California, was officially changed to an oceanographic institution, the first one in the United States. In

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[76] Maienschein, *100 Years Exploring Life*, 126-149.
[77] Maienschein, *Defining Biology*, 51-56.

the 1930's, the University of Washington's Puget Sound Laboratory also incorporated oceanography in its program. The Miami Marine Laboratory is another such example. Its prospectus, quoted by Thomas Barbour, clearly showed that when it was established in 1943, this station was intended to be devoted only to marine biological studies. Yet, three years later, its director Walton Smith wrote that the laboratory had oceanographic as well as marine biology programs. In fact, leading oceanographers such as Columbus Iselin had noticed the station's usefulness very soon after its establishment, and it was indeed used as one of the centers of wartime oceanographic work.[78]

American marine biological stations were, therefore, important in the history of oceanography not only because they were homes of marine biology, one branch of marine sciences, but also because they were the roots of later oceanographic institutions. As many oceanographic institutions grew out of marine biological stations, it is necessary to know the full story of early American marine biology in order to understand the history of American oceanography. At the same time, getting a better understanding of the "magnificent chain of marine biological stations" would also benefit the history of biological sciences, as it would allow us to have a better view of the larger picture of American biology in the late nineteenth and early twentieth century.

[78] Barbour, "Marine Biological Laboratories"; Smith, "Functions and Development of a Tropical Marine Laboratory."

CHAPTER 2
Biology of the Sea: William Emerson Ritter's Program of Marine Biology

In the 1880's and 1890's various marine biology stations flourished in the United States. Most of these stations, including the Marine Biological Laboratory, the most successful and most famous of its kind, were located on the East Coast. There were only a few professional biologists at the small number of universities and colleges on the West Coast. As a result, there was not as much interest in marine biology on the West Coast as among the East Coast biologists. There were, however, a few pioneers who understood the importance of marine biology and marine stations and tried to build marine institutions on the model of the MBL or the Naples station.

In California, the University of California and Stanford University began to build their seaside laboratories at about the same time. David Starr Jordan, who was a prominent ichthyologist, became the first president of Stanford University in 1891. He was led to the study of fish and marine biology in 1873 when he attended Louis Agassiz's School in Natural History on Penikese Island, which was the first seaside biological station in the United States.[1] He was so impressed with Agassiz's teaching and the summer school's program that he decided to devote his life to the study of marine life. As soon as he came to Stanford, he looked for ways to build a marine biological station, which would, he thought, surely add academic strength to his newborn institution.[2]

At the University of California, William Emerson Ritter began to spend

[1] About Louis Agassiz's Penikese School, see Jane Maienschein, "Agassiz, Hyatt, Whitman, and the Birth of the Marine Biological Laboratory," *Biological Bulletin*, 168 (Suppl.) (1985): 26-34.
[2] David S. Jordan, "The Hopkins Seaside Laboratory," *Science*, Vol. 20, No. 496 (Aug., 1892): 76-77; W. K. Fisher, "The New Hopkins Marine Station of Stanford University," *Science*, Vol. 47, No. 1217 (Apr., 1918): 410-412; W. K. Fisher, "The Hopkins Marine Station of Stanford University," *The Scientific Monthly*, Vol. 29, No. 4 (Oct., 1929): 298-303. See also Susan B. Spath, "C. B. van Niel and the Culture of Microbiology, 1920-1965," Ph.D. dissertation, University of California, Berkeley, 1999, pp. 52-84.

summers at the seaside with his colleagues and students in the early 1890s. Like Jordan's station, Ritter's summer program also resembled the East Coast marine stations at the beginning. Having studied at Harvard for some years before coming to Berkeley, he knew the importance of marine biology. He and his group did surveys on the flora and fauna of the California coast, which was barely known to the scientific world at the time. He, like Jordan, believed that it was essential for biologists and students to work on marine organisms and to have experience working at seaside. It was his desire to build a marine biology station in California comparable to those on the East Coast.[3]

Ritter's marine station, which finally moved down to Southern California a few years later, gradually turned away from the kind of marine biology done at other stations, including Stanford University's Hopkins Seaside Laboratory. Biology became only a part of the station and other approaches to the study of the ocean became as important as marine biology. Thus, in the mid-1920's, it was named "The Scripps Institution of Oceanography" and became the first American institution devoted to the study of oceanography. Oceanographer Henry Bigelow remarked in 1929,

> The Scripps Institution of Oceanography of the University of California occupies a position at present unique in American oceanography, because it is the only establishment on the continent that is expressly organized and maintained for the investigation of the problems of this science, without economic bias. The Institution, at its headquarters at La Jolla, California maintains a marine laboratory excellently equipped for physical, chemical, and marine sediments as well as for a wide variety of biological investigations, and operates a research vessel ….[4]

The purpose of this chapter is to see how this unique change took place at the

[3] William E. Ritter, "The Marine Biological Station of San Diego: Its History, Present Conditions, Achievements, and Aims," *University of California Publications in Zoology*, 9:4 (1912): 137-248; Helen Raitt and Beatrice Moulton, *Scripps Institution of Oceanography: First Fifty Years* (San Diego: Ward Ritchie, 1967).

[4] Henry Bryant Bigelow, "Report on the Scope, Problems, and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies," Report of the Committee on Oceanography of the National Academy of Sciences, 1929, p. 101.

Scripps Institution, especially under William Ritter's leadership. What were the factors that led this station to its extraordinary path of development? Here, I will show that Ritter's idiosyncratic philosophy of biology and his peculiar concept of marine biology led him to embark on a unique program of research at his marine station, and that this "marine biology" program gradually led the institution away from other marine biology stations and closer to oceanography.

1. The Beginning of Marine Biology at the University of California

William Emerson Ritter, a young teacher from Wisconsin, came to California in 1885. Impressed by a textbook on geology, he wanted to study with the author, Joseph Le Conte, then Professor of Natural Sciences at the University of California. After spending a year teaching in Fresno to earn his tuition, Ritter entered the University of California in 1886 at the age of thirty. It took him two years to receive his B.S. degree and in 1889 he went to Harvard University for graduate study. In 1891 he returned to California and to his alma mater to become the first chairman of the newly formed zoology department. When he came to Berkeley, he also married Mary Bennett, a young medical doctor whom he had met in Fresno.[5]

Ritter and his bride chose to go to San Diego for their honeymoon trip. For Ritter, this trip was also for his research. The subject of his Ph.D. thesis was the retrograde eyes of the Blind Goby, which could be found at the San Diego shore. The couple spent some time during the honeymoon collecting and studying the fish and other marine life. During their stay in San Diego, the Ritters became acquainted with Dr. Fred Baker and his wife Dr. Charlotte Baker. They were leaders of the community in various aspects, including politics and education, and Fred Baker was also interested in promoting science in San Diego. He was himself an amateur naturalist, who was deeply interested in conchology, the study of sea shells. The common interest in natural history made Ritter and Baker close friends, and years later, Fred Baker was to play a crucial

[5] Raitt and Moulton, *Scripps Institution,* 3-6.

role in drawing Ritter's marine station into San Diego.[6]

From the very beginning of the Department of Zoology, marine biology was considered to be an important part of its scientific program. According to Ritter, his former teacher and colleague Joseph Le Conte "under whose official headship matters zoological in the University then rested, was ever enthusiastically desirous of seeing a seaside laboratory strongly and permanently established, and to this end never failed to use his influence when occasion offered."[7] Ritter, who spent two years on the East Coast as a graduate student at Harvard, was also aware of the need of a marine station. He not only heard of the various marine stations but also had chances to stay and work at Alexander Agassiz's private station at New Port, Rhode Island. Strongly backed by Le Conte, therefore, Ritter soon set out to begin a marine biology program for the zoology department.[8]

Why did Le Conte and Ritter think that a marine station was necessary for their biology program at the University of California? Ritter's ideas about marine biology and marine stations around this period are evident in a letter he wrote in February, 1893.[9] Writing on the biology education of the time, Ritter argued that "[t]here is but one method of true teaching in zoology and botany recognized at the present time. This method is to *help* the learner to gain *knowledge from* the animals and plants themselves rather than to *give* him *information about* them. It aims to instruct and train rather than to instruct alone." To teach students the way to obtain knowledge of animals and plants, there was no better way than to engage them directly in original research, either in laboratories or in the field. The settings in which original research in biology was done included "Universities, Marine Stations, Learned Societies, and several kinds of undertakings by governments." Among these, Ritter wrote, "the Learned Societies were undoubtedly the foremost media for the advancement of knowledge in this direction" until recently. "One who has occasion to familiarize himself with any subject pertaining to American zoology, the literature of which extends back for more than twenty years,

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6 Ibid.

7 Ritter, "Marine Biological Station," 149.

8 For Alexander Agassiz's New Port Marine Laboratory, see Mary P. Winsor, *Reading the Shape of Nature: Comparative Zoology at the Agassiz Museum* (Chicago and London: University of Chicago Press, 1991), 200-212.

9 Ritter's letter to anomymous receiver (Feb. 10, 1893), *William Emerson Ritter Papers*, Bancroft Library, University of California, Berkeley.

will find that it was produced very largely under the auspices of either the Boston Society of Natural History, the Philadelphia Academy of Sciences, the Smithsonian Institute, or the Peabody Academy of Science." However, the scientific leadership of these societies was fading away. In the 1890's, it was no longer easy to find major literatures produced by the learned societies, particularly in the field of animal morphology and embryology, the two areas of zoological science "absorbing the attention of almost all the foremost workers." The scientific leadership had been transferred to universities and marine stations, and this shift was largely due to the change in the nature of biological research. Specialization of biological work and complication of research methods made it inevitable that universities were to become the foremost institutions for the biological sciences. Advanced training for biological researchers was possible only at universities, and university instructors were the main producers of new biological knowledge.

If universities became important for biology because of the changed nature of research, the rise of marine stations was related to the object of biological study. At the time, study of marine organisms was one of the most important areas in biological sciences. Marine organisms, especially small invertebrates, were considered to be the key to many important questions of contemporary biology. William Keith Brooks of the Johns Hopkins University once reported to President Gilman on the work in marine biology done at the marine station of the Johns Hopkins University, that "Nearly every one of the great generalizations of morphology is based upon the study of marine animals, and most of the problems which are now awaiting a solution must be answered in the same way."[10] Marine biological stations were by no means separate from university biologists. As in the case of Brooks' station of the Johns Hopkins University, many marine stations were operated by biology departments of universities. And those not directly run by universities were also closely connected with university scientists. At the Marine Biological Laboratory at Woods Hole, for example, Charles Otis Whitman, professor of zoology at the University of Chicago, was the director of the institution and its main researchers were professors from various American universities visiting the lab during summer vacations.[11] The network of universities and marine biological stations

[10] Ibid.
[11] On the Marine Biological Laboratory at Woods Hole, Massachusetts, see Jane Maienschein, *100 Years Exploring Life, 1888-1988: The Marine Biological Laboratory at Woods Hole*

was, therefore, necessary for the advancement of biological research and education, and it was the main feature of American biology in the late nineteenth century.

It was this combination of university laboratory and marine biological station that Ritter and Le Conte wanted to establish at the University of California. As soon as he took charge of the zoology department, Ritter struggled simultaneously to build laboratories and a marine station. He made his first attempt at marine biology in 1892. Ritter's first choice of location for marine biological field study was Pacific Grove at the Monterey Bay, where he built a seaside laboratory with wood and canvas in the spring of 1892. He spent the summer there with "about a dozen persons, mostly students and teachers." But a building of the Hopkins Seaside Laboratory of the Leland Stanford Junior University was erected at Pacific Grove at that time and "alongside that ample, well appointed laboratory, our little tent-house made a sorry spectacle," Ritter later confessed.[12]

The next summer Ritter and his students, mostly undergraduates, set up a one-time marine station on the shore of Avalon Bay, Santa Catalina Island. Ritter spent the summers of 1894 and 1895 in Europe and others led marine biological study in those summers. An expedition on the coast north of San Francisco was made in 1894 by Samuel J. Holmes, Frank Bancroft and E. W. Horn. Holmes was a recent graduate from the University of California and an assistant in zoology and Bancroft and Horn were undergraduate students. In 1895, a group led by H. P. Johnson spent several weeks in San Pedro Bay. But until 1901 no marine station project was carried out although some sporadic marine expeditions were done, including the Harriman Expedition to Alaska in which Ritter took a part as a specialist in marine invertebrates.[13]

In 1901 and 1902, Ritter resumed his summer station in San Pedro. He and other Berkeley biologists thought that San Pedro Bay was an especially suitable location for a marine biological laboratory because of its favorable natural environment. Here, staff members of the zoology department, including Charles Kofoid and Harry B. Torrey, and graduate students did marine biological study. Kofoid, who joined the zoology faculty in

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(Boston: Jones and Bartlett, 1989); and Frank R. Lillie, *The Woods Hole Marine Biological Laboratory* (Chicago: University of Chicago Press, 1944).

[12] Ritter, "Marine Biological Station," 144-164; See also, Raitt and Moulton, *Scripps Institution*, 3-22; and Philip J. Pauly, *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey* (Princeton: Princeton University Press, 2000), 201-204.

[13] Ritter, "Marine Biological Station," 144-164.

1900, was an experienced researcher of marine and fresh-water planktons. Having done an extensive study of the planktons living in the Illinois River, he was familiar with fieldwork and the use of quantitative and statistical methods in biological research.[14] Two students in the zoology department, Alice Robertson and Calvin O. Esterly, who were at the beginning of their scientific careers at that time, contributed to the biological work, and W. J. Raymond, professor of physics, carried out basic physical measurements of the sea water.[15]

Ritter considered physical study of the ocean to be an indispensable part of marine biological study. Applying for support for publishing results of marine biological study from the Carnegie Institution of Washington, Ritter wrote:

> [The investigation] will be primarily biological. Since, however, biological investigations can be thoroughgoing only when the physical conditions under which life exists are fully known, and since our knowledge of the oceanography of the eastern Pacific Ocean is exceedingly meager, the investigation must deal with the physical conditions of the sea quite as much as with its life. The researches must be hydrographic, chemical, physical, and meteorological as well as biological. In other words, our problem in general is that of gaining a knowledge of the Pacific Ocean adjacent to the North American continent.[16]

It is clear that biological work was the main task; but physical study was also needed for the thorough understanding of the marine life. Here, Ritter even seems to understand the value and necessity of physical oceanography for its own sake.

In the early years of Ritter's marine biology, he and his colleagues seem to have chosen the itinerant model of the Johns Hopkins' marine station.[17] W. K. Brooks' marine biology group, the "Chesapeake Zoological Laboratory," which consisted of his

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[14] Richard B. Goldschmidt, "Charles Atwood Kofoid," *National Academy of Sciences Biographical Memoirs*, 26 (1951): 121-151.
[15] Ritter, "Marine Biological Station."
[16] Ritter's letter to the President and Board of Trustees of the Carnegie Institution, Washington, D.C. (Feb. 13, 1902), *Ritter Papers*.
[17] Ritter's letter to anonymous receiver (Feb 10, 1893), *Ritter Papers*.

colleagues and students at the biology department, went to different places year after year on the Atlantic Coast of the North American continent.[18] Ritter must have had primarily financial considerations, as well as efficiency of work, in mind when he followed the example set by Brooks. The Johns Hopkins' marine laboratory did not need a large amount of money for its operation since it did not possess a permanent building. The group was always kept small in size with the university's professors, instructors, and advanced students as its members, because it was devoted solely to research and not to elementary instruction. Moreover, laboratory apparatus was taken from the university so that only very little additional expenditure was needed for preparing the local laboratory. Despite the small size and meager financial support, however, this migratory marine lab was very productive since it was exclusively research oriented and effectively organized for this end. "Many of the most important contributions to biological science that have been made by American workers during recent years," Ritter concluded, "have come from this simple, inexpensive laboratory."[19] It was natural, therefore, that Ritter thought it to be the perfect model for his own marine station.

In many respects, Ritter's marine station was in a similar situation to Brooks' at the Johns Hopkins University, which justified his decision to use it as a model. Both stations were led by one strong leader, Brooks at the Johns Hopkins and Ritter in California, and they belonged to a single department of a university. The two leaders had a clear vision and long-term plan for the stations' research aims—to obtain extensive knowledge of fauna and flora living on the East and West Coasts of the North American continent, and to conduct advanced research on the marine organisms. Unlike the MBL and the Naples station where visiting workers conducted individual research projects, the leader's influence on the research plan was so great that the group was organized to achieve the overall goals and the work of each member designed to take part in it.[20] This was possible because the workers of these marine biology groups were at the same time

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[18] On Brooks' Chesapeake Marine Zoological Laboratory, see Keith R. Benson, "From Museum Research to Laboratory Research: The Transformation of Natural History into Academic Biology," in Ronald Rainger, Keith R. Benson, and Jane Maienschein, eds., *The American Development of Biology* (New Brunswick: Rutgers University Press, 1991), 49-83; and Philip J. Pauly, "Summer Resort and Scientific Discipline: Woods Hole and the Structure of American Biology, 1882-1925," in the same volume, 121-150.
[19] Ritter's letter to anonymous receiver (Feb 10, 1893), *Ritter Papers*.
[20] On the MBL and the Naples Station, see the essays in *Biological Bulletin*, 168 (Suppl.) (1985).

members of the biology or zoology departments where the influence of the two leaders was overwhelming.

Run at a departmental level, the small budget must have been a factor in Ritter's considerations. Unlike David Starr Jordan's station which found an enthusiastic patron Timothy Hopkins, Ritter's marine lab could not spend too much money on the summer program, which made it impossible to acquire a permanent building for the station.[21] In this respect, Brooks' marine lab was, again, a perfect model. The itinerant model was, in fact, a timely one for Berkeley's burgeoning marine station. At the time when the Pacific Coast was almost totally unknown to scientists, an extensive survey rather than the intensive study of a small region was more appropriate. In 1901, Ritter wrote to Edward H. Harriman about his grand plan for the Pacific Coast survey which would extend "from Point Barrow to Cape Horn, covering as thoroughly as possible all the intermediate territory. In this way the investigations would extend from well into the Arctic regions, across the Equator, and into the southern hemisphere."[22]

Probably having gotten no promising response from Harriman and others for the support of his Pacific survey program, Ritter seems to have given up the plan and become skeptical of the migratory research program. Instead, Ritter and his colleagues began considering the building of a permanent laboratory and discussing the best location for it. From the many years of experience at several different locations along the California coast, the Berkeley biologists easily arrived at the conclusion that San Pedro was the best place for their permanent marine station. They soon learned, however, that the harbor was rapidly growing to become a place of commercial activities and that a large urban population would gather within a few years. The San Pedro Bay area therefore no longer was a good candidate for the laboratory site since it seemed inevitable that the seawater would soon be contaminated and the scientific fieldwork at the coast would be significantly disturbed.[23]

At this time Dr. Fred Baker of San Diego heard of the situation that the University of California zoologists were facing and their new plan for a permanent station. Believing that San Diego might be a suitable location for the marine biology station, he thought that it was a good chance for San Diego. He soon began to persuade

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[21] On Timothy Hopkins' contribution, see Fisher, "New Hopkins Marine Station."
[22] Ritter's letter to Edward H. Harriman (Feb. 20, 1901), *Ritter Papers*.
[23] Ritter, "Marine Biological Station," 148-164; Raitt and Moulton, *Scripps Institution*, 12-22.

Ritter and his colleagues to come down to his hometown and build a station there. Baker, himself an amateur biologist, was confident of the adequacy of the area as the location for a marine biological station. Moreover, he was deeply concerned about the future of the city of San Diego and was aware that a prominent scientific institution would surely contribute to the city's reputation. Therefore he attracted Ritter with a promise of organizing the city's leading citizens to support the marine station.[24]

Having worked in San Diego during his honeymoon for his Ph.D thesis, Ritter was aware of the area's favorable conditions for the study of marine biology. Charles Kofoid went to San Diego for a preliminary expedition in 1901 and reported that he, too, was satisfied with the natural setting of the area. The decision was made, finally, to open a marine biological station in San Diego.

2. The "Marine Biology" Program at the Marine Biological Association of San Diego

The University of California's biologists spent the summers of 1903 and 1904 in Coronado with the laboratory quarters in the boat-house of the Coronado Hotel Company. Here, the official name "Marine Biological Association of San Diego" was given to this enterprise, and the year 1903 marks the beginning of the history of the Scripps Institution of Oceanography. With the help of a newspaper magnate and local philanthropist Edward W. Scripps and his stepsister Ellen B. Scripps who joined the board of directors, the laboratory purchased land and moved to La Jolla in 1905.[25]

As the University's marine station found its permanent home, Ritter felt the need to articulate a new research program for his new institution. The new plan was needed not only to please the new patrons and the University's high officials but also to set the researchers on a new direction of research suitable for a non-migratory research group. The old program based on the itinerant model did not work any more and,

[24] Ibid.
[25] Ibid.

therefore, Ritter carefully re-articulated the concept of marine biology and made a new research program for his new laboratory. In 1905, he published an article in which he delineated his ambitious ideas and plans for marine biology.[26] "A General Statement of the Ideas and the Present Aims and Status of the Marine Biological Association of San Diego" begins with Ritter's definition of marine biology and his distinction between it and the "general biology prosecuted by researchers on marine organisms."

> *Investigations in marine biology, intensive rather than extensive in character* (to borrow a useful agricultural phrase) is the key note of the idea. An Immediate consequence of the adoption of such an idea as a rule of action, has been the necessity of making a clear distinction between *marine biology*, and *general biology prosecuted by researchers on marine organisms*. . . . The former has for its aim, in the large, the getting of as comprehensive an understanding as possible of the life of the sea. It, of course, presents itself under a great variety of secondary questions; but the sum total of the phenomena of *marine* plants and animals will never be lost sight of as its real aim. The latter makes use of animals and plants that live in the sea in general biological researches. That these organisms happen to be marine is an incident merely. The investigator turns away from them without hesitation when others, from whatever source, come to hand that suit his purpose better. Further, the user of marine organisms in such investigations is quite indifferent to everything concerning them that does not bear upon his particular problem. He puts aside the marine animal after it has served his purpose without having even noticed, perhaps, the major part of its traits and qualities and the questions concerning it.[27]

Here Ritter made it clear that he no longer aimed at the "extensive" survey of the whole Pacific Coast that he once pursued with his migratory group of researchers, and would

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[26] William E. Ritter, "A General Statement of the Ideas and the Present Aims and Status of the Marine Biological Association of San Diego," *University of California Publications in Zoology*, 2 (1905): i-xvii.
[27] Ibid., ii.

instead conduct an “intensive” investigation of marine biology.

What did Ritter mean, then, by the term “intensive investigation”? Having abandoned the grand plan of surveying the Pacific Coast from the Arctic regions to the Equator, from the North American Continent to the South America, he now decided to focus on a much smaller area adjacent to the station by setting a clear geographical boundary. Thus, the aim of the Association now became, “To make a Biological Survey of the waters of the Pacific adjacent to the Coast of Southern California.” The “irregularly triangular area extending from Point Conception, Lat. 34º 27’, at the north, to a base line extending westward from the southern boundary of the United States, Lat. 32º 28’, bounded on the east by the coast line, and on the west by the meridian of Point Conception, Long. 120º 25’” was decided to be the region to be scrutinized.[28] Ritter could justify the choice of this research area by enumerating its advantages: “a position well to the south; a considerable extent of continental shelf, presenting a large diversity of bottom, with numerous islands and shoals; proximity to oceanic depths and other truly oceanic conditions; a favorable climate; a large variety of shore line; and accessibility through sea ports and railroads.” The fine climate of the region was an important condition because it guaranteed “*continuousness* of the field work.” Before settling in La Jolla, the group of researchers did not have to care about the yearlong weather condition of the region since what mattered to them was only the summertime. But now at the new station they were planning to do continuous field work to study daily, seasonal and yearly changes in the lives of marine organisms.

Within this area, the Marine Biological Association of San Diego would pursue “as comprehensive an understanding as possible of the life of the sea.” It did not mean just the morphological and embryological knowledge of some marine animals that the researchers at the Johns Hopkins’ marine station and others pursued. It included taxonomical, morphological, physiological, and ecological knowledge of all the animals and plants inhabiting the region. Ritter did not try, however, to achieve all of these goals at once, and made a step-by-step approach in his research program. Admitting that the station was situated “on a biologically almost unknown part of a little known ocean,” the initial step taken was naturally a taxonomical study of theoretically all the organisms living in the area. By the time Ritter was writing this plan, this work had been carried on

[28] Ibid., iii.

for some years since the research area included some of the places they had worked before moving down to San Diego. Usually a group of the local fauna was allotted to a researcher of the station: for example, hydroids and ctenophores to Harry B. Torrey, pelagic copepoda to Calvin O. Esterly, nonencrusting cheilostomatous bryozoa to Alice Robertson, dinoflagellata to Kofoid, and pelagic tunicata to Ritter.[29] The taxonomical work, Ritter emphasized, had to be something more than the "mere description of the new species for the exclusive use of expert taxonomists," and "the entire fauna and flora must be recorded in such a way as to make the records a good foundation for the broader and deeper studies to follow." Ritter expected that the initial step of taxonomical work would result in the "hand-books" that would be used in the next steps of biological research.

After the fundamental taxonomic survey, according to Ritter, ecological lines of study were to ensue. If a general taxonomy of a group of marine organisms were known, then the next step would be the "determination of the seasonal distribution of the group." The chorology, i.e. the "horizontal and vertical distribution," had to be studied next. Then, the problem of their "food and reproduction" had to be known in relation to the horizontal and vertical distribution. And finally the "problems of migration, with their intimate dependence upon temperature and other environmental factors" were to be attacked. And here, for the sake of "completeness of knowledge," it was necessary to apply "experimental and statistical methods."[30]

Ritter was also well aware of the indispensability of the physical knowledge of the ocean for the study of marine biology. Ritter's marine biology program required its researchers to know enough of the relevant physical conditions of the marine environment where their animals lived. It was, indeed, what made their work "marine biology" as contrasted with the "general biology prosecuted on marine organisms." The peculiar structures, functions, and behaviors of the marine animals and plants that enable them to adapt themselves to and live in the marine environment are what make them truly "marine." And it had to be the goal of true "marine biologists" to understand them

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[29] Ibid., vii-viii.

[30] Ibid., vii-viii. Resident scientist Ellis Michael went farther to assert that ecology was not the end of marine biology. He seems to have conceived of an order of doing marine biology: (taxonomy)→(ecology)→(morphology, physiology, embryology, cytology, etc). Ellis L. Michael, "Dependence of Marine Biology upon Hydrography and Necessity of Quantitative Biological Research," *University of California Publications in Zoology*, 15 (1916): i-xxiii. See esp. iii-ix.

properly. Therefore, biologists had to be familiar first with the unique conditions of the oceanic milieu in order to know the way marine organisms react to them. Particularly, the biological problems as outlined above could not be studied properly without relevant data on the physical, chemical, and geological environment of the marine organisms in question. To understand such marine ecological problems as the causes of vertical and horizontal distribution, seasonal changes of distribution, migration, food and the reproduction processes of certain marine organisms, "Conditions of the water as to temperature, and currents; mineral, gaseous, and albuminoid content, etc., must be known at *the particular time and place to which the biological studies pertain*, and no general knowledge of this character can suffice."[31] It meant a need for regular physical measurements and investigations that could not be done by visiting researchers who worked only during the summer. Thus, Ritter asserted that "Physics, chemistry, and hydrography must, therefore, be integral parts of such a survey" at the Marine Biological Association. At the time, it was W. J. Raymond, assistant professor of physics at the University of California, who had been conducting the measurements of water temperature, density and salinity in the area for several years. Later, George F. McEwen, a young physical oceanographer, joined the Association as a part-time worker in 1908 and became a permanent member in 1911. Ritter did not, however, consider the physical study an independent line of work at the Marine Biological Association, although he seems to have been aware of the value of physical oceanography since an earlier period. It was to be done only to support the study of "marine biology."

Ritter's leadership in matters of scientific work at the Association was dominant throughout the years of his directorship. Choosing the lines of research, hiring of staff members, and organizing their scientific work were all in the hands of Ritter. The San Diego Marine Biological Association was more or less a tightly organized research team in this respect, and it differed significantly from other marine biological stations that sold tables to other institutions.[32] It was apparent in the Association's policy regarding

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[31] Ritter, "A General Statement," viii-ix. See also Michael, "Dependence of Marine Biology," xvi-xxi.

[32] At Naples, the Fish Commission Laboratory, and the MBL, institutions paid for a right to use a table or a laboratory for their researchers or students who visited those places each year. Maienschein, *100 Years Exploring Life*, 55; Maienschein, "Early Struggles at the Marine Biological Laboratory over Mission and Money," *Biological Bulletin*, 168 (Suppl.) (1985): 192-196.

visitors. Ritter allowed, if not welcomed, occasional outside visitors during summers whenever lodges and working spaces were available, and he did not prevent them from doing their own researches whether or not they conformed to the Association's research program. They were accepted, however, merely as a service to the academic world and for the purpose of spreading the institution's reputation as the leading marine station on the West Coast. The main work at the station strictly followed Ritter's plan. The "ecological problems of oceanic plankton, and of bottom-forms" had been "attacked under peculiarly favorable conditions" of the San Diego vicinity. Thus, the marine biology program, as articulated by Ritter, continued to be the main research program at the Marine Biological Association, and the marine ecological research in conjunction with the physical oceanography continued to dominate its scientific work.

3. Marine Biology as a Holistic Field Science: Ritter's Biological Philosophy behind the Research Program

The research program of the San Diego Marine Biological Association, which we call the "marine biology program" in this chapter, aimed at the comprehensive understanding of the life phenomena at sea. Ritter and his colleagues wanted, eventually, to understand "the sum total of the phenomena of marine plants and animals" living within the boundary they drew. It was not easy to find similar projects in the United States and elsewhere at the time. How, then, did Ritter come to have such an idea? Where did it come from? To find answers to these questions, we have to first take a look at Ritter's philosophical thinking.

Ritter was deeply interested in the philosophical basis of biology and devoted much of his time to writing and publishing his ideas. *The Unity of the Organism: Or the Organismal Conception of Life*, which was published in 1919, may represent these endeavors.[33] "In its earliest infancy," states Ritter, "the science of living beings

[33] Ritter, *The Unity of the Organism: Or the Organismal Conception of Life*, 2 vols. (Boston: R.G. Badger, 1919).

presented two theories apparently diametrically and irreconcilably opposed to each other." According to one theory, which Ritter called "elemental theory" or "elementalism," "the organism is explained by the substances or elements of which it is composed." According to the other opposing theory, on the other hand, "the substances or elements are explained by the organism." For this latter view, Ritter coined the terms "organismal theory" and "organismalism." He also used the terms "Lucretian" and "Aristotelian" to denote the ideas according to the names of the earliest representatives of them.[34] To explain the essence of the organismal theory further, Ritter cites from Aristotle's *On the Parts of Animals*:

> But if man and animals and their several parts are natural phenomena, then the natural philosopher must take into consideration not merely the ultimate substances of which they are made, but also flesh, bone, blood, and all other homogeneous parts; not only these, but also the heterogeneous parts, such as face, hand, foot, and so on. For to say what are the ultimate substances out of which an animal is formed … is no more sufficient than would be a similar account in the case of a couch or the like. For we should not be content with saying that the couch was made of bronze or wood or whatever it might be, but should try to describe its design or mode of composition in preference to the material. … For a couch is such and such a form embodied in this or that matter, or such and such a matter with this or that form. … It is plain, then, that the teaching of the old physiologists is inadequate, and that the true method is to state what are the definitive characters that distinguish the animal as a whole; to explain what it is, both in substance and in form, and to deal after the same fashion with its several organs.[35]

Ritter then went on to explain the development of the two ideas in the more recent period "from Linnaeus' *System of Nature* to Darwin's *Origin of Species*." Here he pointed out that the course of history had often been interpreted incorrectly, as if it

[34] Ibid., 1-26.
[35] Ibid., 2.

“constitute[d] a virtual proof of the correctness of the elementalist theory.” It had often been said, according to him, that “in the Linnean era plants and animals were treated from the standpoint of the organism as a whole.” Later, however, under the leadership of Cuvier, “instead of the complete organism, the organs of which it is composed became the chief subject of analysis.” Then, it was Bichat who brought the object of biological study down to the level of tissues. With the work of Schleiden and Schwann, it was soon discovered that “not the tissues but the cells are the real units of structure.” Finally, “with the demonstration, accomplished chiefly by Max Schultze, that one substance, protoplasm, is the common basis of life in plants and animals, real biology was attained.” According to this version of progressive history, there had been a gradual progress in the biological sciences eventually leading to the ultimate victory of the elementalism.

This interpretation was not flawless, however. Ritter pointed out that it was a total misunderstanding to treat Cuvier, and the group of French biologists represented by him, as elementalist.[36] In fact, “The distinctive feature about the school was not the idea of the organs as such, but as parts of the whole. The ensemble, the principles of co-existence, or correlation, or subordination of organs and “characters,” are what stand out most prominently in the writings of these men, so far as general conceptions are concerned.” Cuvier made it clear in *Researches on Fossil Fishes*: “Every organized being forms a whole, a system unique and closed, of which the parts mutually correspond and concur in the same definitive action through a reciprocal reaction. No part may change without the others changing also; and consequently each of them, taken separately, serves as an index and an exposition of the others.” Included in this French school were such men as Geoffroy Saint-Hilaire and the Jussieus, uncle and nephew, from whom Cuvier himself might have adopted the view.

Ritter admitted that there had been a period when the elementalist view dominated biological sciences.[37] Owing to the vigorous influence of the cell theory, “the organismal conception lay almost wholly dormant during the fifty years from 1840 to 1890.” The organismalism, however, had returned to the scene since 1890. This reanimated organismalism was a rather new one having almost nothing to do with the

[36] Ibid., 5-7.
[37] Ibid., 8-10.

old French school led by Cuvier. It was born out of the "growing recognition of the inadequacy of elementalism as bodied forth in the cell theory applied to the development of individual organisms." Ritter particularly mentioned three American biologists whose work in embryology and cytology best exemplified the advent of the new epoch of organismalism. They were C.O. Whitman, E.B. Wilson and F.R. Lillie. Whitman, for example, had initially held the elementalist view, but having realized its inadequacy in dealing with the problems of embryology, later turned to organismalism. Lillie's statement shows very well the idea shared by these three biologists:

> If any radical conclusion from the immense amount of investigation of the elementary phenomena of development be justified this is: That the cells are subordinate to the organism, which produces them, and makes them large or small, of a slow or rapid rate of division, causes them to divide, now in this direction, now in that, and in all respects so disposes them that the latent being comes to full expression. … The organism is primary, not secondary; it is an individual, not by virtue of the coöperation of countless lesser individualities, but an individual that produces these lesser individualities. … The persistence of organization is a primary law of embryonic development.[38]

The work and thoughts of these biologists and others had clearly shown the appropriateness of the organismal view as the basis for future biological research. Having briefly examined the recent history of both elementalism and organismalism, Ritter now quite confidently prophesied the impending demise of the former and the eventual domination of the latter.

> Viewed broadly both as to historical development and factual content, we are warranted in being confident of the triumph of the organismal standpoint at a day not far distant, this confidence being warranted largely by the fact that it seems as though elementalism has run nearly its whole natural course. It has consumed all the material there is for it

[38] Ibid., 14.

> to live on, as one may say. It is now engaged in trying out the very last portion of the organism as the "seat" or ultimate explanation of life phenomena.[39]

What does it mean, then, to study the "organism as a whole" in biology? Ritter first warned that it is far from right to assume that "to take the organism in its entirety is to take it unanalyzed." He argued that organismalism does not deny the validity of analytical knowledge in the science of biology. To him "the organism as a whole" meant "nothing less than the organism *and* all of its parts" since "The whole would not be the whole if some of its parts were omitted." Organismalism required researchers to study every part of an organism, neglecting nothing in it. What was problematic in the strong reductionism of the elementalist theory was not that they emphasized analysis but that they stopped there and considered the analytic knowledge as the ultimate goal of their scientific enterprise. Biologists had to take the next proper step from there—to arrive at "synthetic knowledge." Ritter contended that "synthetic knowledge of nature is not only valid … but … is as foundational and essential a part of science as is analytic knowledge." Getting to the synthetic knowledge from analytic knowledge was the essential step to truly understand "Organismal Integrity." Knowledge about the organism as a whole could also mean integrated knowledge of an organism. Ritter was aware of the necessity of both an analytic and a synthetic approach in biological research, and the combination of the two might be the essence of his organismal theory. Thus he formulated his central idea as follows: "*The organism in its totality is as essential to an explanation of its elements as its elements are to an explanation of the organism.*"[40]

Understanding the interrelationship among the parts was the key to attain the synthetic knowledge of the organism as a whole. Ritter pointed out that "The term most characteristic of this latest outcrop of organismalism is correlation." It was "the correlatedness of parts in the organism" in the sense of both structural and functional aspects that scientists had to study. "Equilibrium" was another term frequently used by the biologists who took the organismal approach, and it was closely related to Saint-Hilaire's term "balance." For C. M. Child and other biologists, the doctrine of

[39] Ibid., 20.
[40] Ibid., 24-26. Emphasis is Ritter's.

"physiological correlation" was most important, and at the core of the work of scientists like H. Driesch there was the conception of "harmonious equipotential systems." To sum up, at the basis of Ritter's organismal theory was the idea that the structure and function of the parts of an organism are closely "correlated" with one another and, as a result, the "organism as a whole" is in the state of "equilibrium," "balance," or "harmony." Therefore it may be the natural conclusion that the goal of biologists should be the understanding of these relations and equilibrium.[41]

Eric Mills, a historian of oceanography, argued that Ritter's holistic philosophy, or the organismal conception of life, was largely original, with some influence from Henri Bergson, who wrote *Evolution Creatrice* around this period, and Alfred North Whitehead, who articulated a theory of organisms in *Science and the Modern World*.[42] Ritter also acknowledged his indebtedness to German thinkers such as Alexander von Humboldt and Carl Ritter. Nevertheless, recent developments in biological sciences must have been the main source of inspiration to Ritter, not to mention the direct influence from frequent discussions with his colleagues in La Jolla and Berkeley, such as Charles Kofoid, Samuel J. Holmes, Ellis Michael, and George McEwen.

If we compare Ritter's organismalism with his program of marine biology at the San Diego Marine Biological Association, the similarity between the two becomes clear immediately. Organismal biology aimed first at understanding everything about all the parts of an organism and, then, showing the correlation among them. Marine biology researchers first tried to know all the species living in the portion of the sea and, then, went on to investigate the ecological relationships among them and also with their physical environment. In applying the idea of organismalism to marine biology, one thing that had to be done was to extend the notion of the organism as a whole to the sea as an organism, which might well include the physical marine environment. In Ritter's understanding of marine biology, then, the ocean as the sum of living organisms and their physical environment corresponded to the organism as a whole; animals, plants, and the physical conditions of the sea were the parts constituting the organism. As Ellis Michael, resident naturalist of the institute, once put it, "Intensive rather than extensive research in marine biology is the leading idea of this survey, and, although this involves

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[41] Ibid., 26.

[42] Eric L. Mills, *The Scripps Institution: Origin of a Habitat for Ocean Science* (La Jolla: Scripps Institution of Oceanography, 1993).

the acquisition of detailed information concerning particular marine organisms, knowledge of the biology of the sea is the ever-present ideal."[43] For Michael as well as for Ritter, therefore, marine biology was the "biology of the sea."

Closely related to the notion of marine biology as an organismal science was the problem of the relationship between laboratory experimentation and fieldwork in biology. Ritter, in many ways, belonged to the tradition of natural history, which preferred field study to laboratory work. Most marine biologists who belonged to his generation shared this attitude. David Starr Jordan, founder of the Hopkins Marine Station, for example, was an ardent advocate of the natural history approach in marine biology. In an address he gave at La Jolla in 1916, he praised the "old-fashioned natural history" and warned the incompleteness and danger of experimental biology.[44] He argued that "an experiment is often the easiest line of attack, but it may also be the most deceptive." "In biology," he continued, "facts are individual. No two objects are ever exactly alike, hence the relative futility of biometric versions of its problems." In this address, he expressed his wish to appreciate the kind of biological work done at Ritter's station. He must have been pleased that Ritter and his colleagues were following the ideas and methods of the "old-fashioned natural history." Jordan must have been unhappy and worried about the contemporary tendency of weakening of naturalistic biology in the United States and, perhaps, might have foreseen the events that were to happen in later years at Stanford University. Ray Lyman Wilbur, President of Stanford, reformed biological sciences at the university and made the Hopkins Marine Station home to experimental biology together with its non-experimental marine biology program centered on fishery science.[45]

In many places Ritter, too, addressed his ideas about laboratory and field work in marine biology. In general, Ritter had a more balanced view on this issue. To him, to understand marine organisms fully meant to understand them both morphologically and physiologically. "A combination of observation and experimentation" was necessary for that end.[46] As a biologist trained in morphology, Ritter nevertheless understood the need

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[43] Michael, "Dependence of Marine Biology," i-xxiii.

[44] David Starr Jordan, "Plea for Old-Fashioned Natural History," *Bulletin of the Scripps Institution for Biological Research*, 1 (1916): 3-6.

[45] Spath, "C. B. van Niel," 52-84.

[46] Ritter, "General Statement," xiv-xvii. See also, Calvin O. Esterly, "Field Research and Laboratory Experiment: Their Places in Ascertaining and Explaining Habits in Nature," *BSIBR*,

for experimental work in the laboratory. Experimentation always had to be preceded by observations in the field. Laboratory work alone can produce no meaningful results. "I verily believe," wrote Ritter, "the value of the experimental and statistical methods now so largely used in biology is not fully appreciated even by some of the most skillful and constant experimenters themselves, nor will it be until these methods are better coordinated with observation in Nature."

> The problems of animal migration, to be specific, we now know depend largely, at least so far as the simpler aquatic forms are concerned, on purely physiological reactions to temperature, light, sex relations, food, etc.; and we are already in possession of important clues to the way these questions must be studied; but we must learn, through careful and extended *observation of the animals in nature*, just what it is we have to interpret. Need for a kind of marine biological research not specially felt a few years ago is now becoming urgent.[47]

In Ritter's view, since life phenomena in nature can never be replicated in laboratories, any lab work not properly complemented by field observation was futile. For Ritter, the priority of field work over lab work was, therefore, established. Basically, experimental method was to be used to supplement the marine biological work done at sea. But, at the same time, field work always needed help from laboratory experimentation. The combined use of both methods was ideal, according to Ritter.

Calvin Esterly's work on the copepod *Eucalanus elongatus* best illustrates Ritter's idea. From his field study, Esterly found that this species does not exhibit any regular up-and-down migration unlike most other plankton species. To explain the phenomenon, he postulated that the unusual transparency of the organisms provided them with the necessary protection from their predators, which other species could not enjoy. Thus, the animals of this species had no need of any regular migration to protect themselves. Esterly now turned to laboratory experimentation in order to test the hypothesis, and was able to prove it. Such experimental lab work, combined with active

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4 (1917): 3-15.

[47] Ritter, "General Statement," xvii.

field work at sea, together constituted Esterly's marine ecological research on planktons at the Marine Biological Association.[48]

Marine biological work at Ritter's station was also successful in adopting mathematical, statistical, and physical methods. Particularly, the plankton study done by such biologists as Kofoid, Esterly, and Michael made an extensive use of statistics and it consciously correlated the life patterns of marine organisms with the physical properties of the sea. The researchers not only made use of physical data already available to them but also conducted physical and statistical work themselves in collaboration with the station's mathematical physicist George McEwen. McEwen did conduct his own research at the station, which was purely physical, but much of his time was devoted to the collaboration with biologists, especially Michael. The Association's biology consciously adopted methodology and techniques from experimental laboratory biology and even directly from the physical sciences.

Ellis Michael also shared with Ritter the view that in marine biology field work as well as lab work is indispensable. Experimentation in laboratories alone, without corresponding field observations, would never produce true knowledge about nature. He wrote, "Experiments conducted in a laboratory … *reveal only what transpires in a laboratory and are necessarily incapable of revealing what occurs in nature*. … [N]o method of laboratory experimentation can reveal the natural behavior of an organism unless it is possible to re-create nature in miniature."[49] Michael continued, "Even if certain environmental conditions can be reproduced in a laboratory, the total complex cannot be duplicated." This is true, especially, in the case of marine biology because the large-scale, long-term oceanic conditions were impossible to replicate in a laboratory. Like Ritter, Michael also arrived at the conclusion that the "Laboratory experiment and field observation must go hand in hand."

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[48] Examples of such ecological work are: Calvin Esterly, "The Vertical Distribution of Eucalanus clongatus in the San Diego Region during 1909," *UCPZ*, 8:1 (1911): 1-7; Ellis Michael, "Classification and Vertical Distribution of the Chaetognatha of the San Diego Region," *UCPZ*, 8:3 (1911): 21-186; and Esterly, "Vertical Distribution and Movements of the Schizopoda of the San Diego Bay Region," *UCPZ*, 13:5 (1914): 123-145. Laboratory studies include, Esterly, "Specificity in Behavior and the Relation Between Habits in Nature and Reactions in the Laboratory," *UCPZ*, 16: 20 (1917): 381-392; and Esterly, "The Occurrence of a Rhythm in the Geotropism of Two Species of Plankton Copepodes When Certain Recurring External Conditions are Abundant," *UCPZ*, 16:21 (1917): 393-400.

[49] Michael, "Dependence of Marine Biology," i-xxiii.

> The former cannot, except by inference, ascertain the manner in which a species is related to its environmental complex. The latter cannot, except by inference, ascertain the nature of response involved in correlations observed between marine organisms (or any other kind of organisms) and their environments. Observation alone cannot determine whether the observed correlations are due to tropisms, trials and errors, or some indirect metabolic reactions. Experiment alone cannot reveal the fact that *Sagitta bipunctata*, for example, is usually more abundant between fifteen and thirty fathoms than at any other depth; that it decreases in abundance below this depth much more slowly than it does above; that it maintains its maximum abundance at higher levels during the summer (July to October) than during the winter (November to March); that it decreases in abundance as the distance from the coast increases at all depths above twenty fathoms, while it increases in abundance at all depths below thirty fathoms, etc. These facts pertain to the species' behavior and have played their rôles in its evolution just as certainly and to fully as great an extent as is the case with any facts of behavior demonstrated in a laboratory. Assuredly, both sorts of investigation are required in order to approach, even remotely, complete knowledge of the behavior of any species.[50]

Historian Robert Kohler recently applied the concept of geographic borders between two cultures to the study of the history of biology.[51] He argued that from the late nineteenth century to the early twentieth century there existed a border region between laboratory biology and field biology where active interactions took place. The relationship between the two cultures was, however, asymmetrical. There, on the border region, biologists trained in naturalistic field biology tried to build border sciences that adopted the methods, practices, and rules of laboratory biology. From this perspective, Ritter's marine biology may be viewed as a border science. Ritter and his colleagues

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[50] Ibid., xv.

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

adopted laboratory experimentation, emphasized the use of statistical and mathematical methods in the study of marine biology, and collaborated with physical scientists, such as McEwen. With his program of marine biology at the San Diego Marine Biological Association, Ritter wanted to build a "new natural history" which would benefit from the advantages brought in from both sides of the border, and that would eventually become a model for other natural-history oriented biologists to follow.

4. Away from the Marine Biology?

From the beginning, the board members of the San Diego Marine Biological Association wanted their enterprise officially incorporated into the University of California as a research department or a similar form of affiliation.[52] These patrons did not want it to remain a small private station supported only by the small number of local wealthy people. They wanted a secure source of annual income for the Association other than their own limited pockets, one which would come out of the University's, and ultimately the state's, budget. But the more important reason was that they wanted the station to gain prestige and a permanent status by becoming a property of the state university. Thereby they would have the guarantee that their philanthropic investment would not end up as a futile one-time effort. It was a reasonable wish because most of the scientific staff of the marine station consisted of Berkeley faculty or students, and the station operated in fact as an affiliation of the University's zoology department whose chairman was at the same time its scientific director. They had a fairly good prospect as well since the president of the University, Benjamin Ide Wheeler, had been very supportive of Ritter's venture since the 1890's. So, as early as 1903, E. W. Scripps made that idea clear: "It is known that there are a number of public spirited and wealthy citizens in this locality who will take sufficient interest in this work to provide all the necessary means, providing the University Regents will, by their action in the matter, recognize the value and use of the station by making it a part of, or branch department,

[52] Ritter, "Marine Biological Station," 148-163.

of the University."[53]

The reality was not that simple though. Ritter arranged several times for the board members to hold direct meetings with President Wheeler and other university officials and regents, and they all had a very favorable impression of the intentions and activities of the San Diego Marine Biological Association. They even succeeded in persuading George C. Pardee, then Governor of the State of California and a regent of the University, of the importance and value of the scientific work at the station during their meeting at E. W. Scripps' Miramar Ranch.[54] All of these People agreed on the basic premise that the Association's affiliation with the University would be beneficial and would be realized in an appropriate future. In the meantime the University did "cooperate" with the Association by making loans of scientific equipment and some books for its library as well as supporting the publication of the results of the work at the station. The regents were, however, reluctant to incorporate the station officially because of the cost of the enterprise. The University was already having difficulty supporting its affiliated research institutions such as the Lick Observatory. The official affiliation had to wait until 1912 when the Board of the Association and the Regents of the University finally agreed upon the transfer.[55] It was decided that "All property, real and personal, together with all rights, franchises and interests of any kind whatsoever ... are vested in the Regents of the University of California," while "the local control of the property, and the business and scientific policy shall be vested in a Local Board of Directors." Thus the rights and responsibilities of each party were clearly set.

With the official transfer of the station to the University came the necessity to give it a new name. Soon it was decided that the new name of the station be "The Scripps Institution for Biological Research of the University of California." It was the named after E.W. and Ellen Scripps' deceased brother George H. Scripps even though it did not include his whole name. E.W. Scripps initially wanted his sister's name also to appear in the institution's official name but Ellen Browning did not want it.

What is rather problematic in this name change in the long run in the station's historical development was the part "for Biological Research." Why "The Scripps

[53] Letter from E. W. Scripps to Fred Baker (August 12, 1903), *William E. Ritter Papers*. Scripps Institution of Oceanography Archives.
[54] Raitt and Moulton, *Scripps Institution*, 23-25.
[55] Ibid., 56-66.

Institution for Biological Research" and not "The Scripps Institution of Marine Biology"? Was it a sign of a change in its scientific research? Perhaps not, since Ritter did not make any mention of a new, different research project and merely repeated the 1903 version of his marine biology program in the report "The Marine Biological Station of San Diego: Its History, Present Conditions, Achievements, and Aims" published in March, 1912.[56] Even though the new name did not bring about a shift of the institution's research, however, it did reflect the wider scope of Ritter's ambition. In the short announcement of the new status and the new name of his station, which preceded the 1912 report mentioned above, he wrote "Although, as indicated by the change of name, an enlargement of activities is contemplated, no immediate alteration of policy or work will take place." In the same year, in his report to the President of the University, Ritter also wrote,

> One may hope that the dropping of the word 'marine' from the name will not be taken to mean that a relinquishment or even curtailment of researches at sea is contemplated. The reason for the change was that those chiefly responsible for the enterprise, whether as financial supporters or essential custodians, had become fully convinced that biology in the largest sense ought to be the aim of this particular foundation. It is not to be supposed that anyone connected with the institution contemplates researches in the whole range of sciences of organic being, particularly at any one time. It is believed, however, that an endowed institution with no special limit of duration, ought to have the utmost freedom as to the particular provinces of the vast domain of biology that it should cultivate at different periods of its existence.[57]

Now that the institution was intended to conduct researches in the whole domain of biology, not just the biology of marine organisms, it came to embrace Ritter's organismal philosophy more thoroughly.

As Ritter made it clear in the above passages, the main line of work at the

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[56] Ritter, "Marine Biological Station," 210-234.
[57] Raitt and Moulton, *Scripps Institution*, 65-66.

station was still the ecological study of marine planktons, mainly done by Calvin Esterly and its resident scientist Ellis Michael who closely cooperated with physical oceanographer George McEwen. Their work on the ecology of marine planktonic animals combined field and laboratory approaches as well as study of the physical conditions of the ocean quite successfully. Ritter also did his part of the plankton study even though it came to a halt in 1913, and Charles Kofoid, who, as the chairman of the Zoology Department, now did not have much time to stay at the station himself, still continued the work on dinoflagellata. In addition, marine biologist Wesley Clarence Crandall joined the institution in 1913 mainly as a business manager of the institution but later conducted important researches in marine biology. Finally Winfred E. Allen, a researcher of phytoplanktons, began to work at the institution in 1917.

The Scripps Institution's broadened program of research began to take effect in 1913, however, with the addition of Francis B. Sumner to the institution's scientific staff.[58] At first glance, hiring of Sumner may not seem an aberration from the station's focus on marine biology, because Sumner had for a long time been associated with the marine biological survey at the laboratory of the U.S. Bureau of Fisheries at Woods Hole, Massachusetts. What made him a symbol of the institution's new direction was his proposed new line of research on the experimental study of evolutionary processes with a genus of deer mouse, *Peromyscus*. It was a very ambitious project to which no other biological work could really be compared. It aimed at studying the contemporary problems of evolution and genetics by conducting extensive breeding experiments on several geographic races of *Peromyscus* for a long period of time. It was an extraordinarily large project which required a large amount of funding. Also, it did not fit very well with the overall work at the Scripps Institution, which mostly dealt with marine invertebrates. Sumner's research on *Peromyscus* rather matched well with the focus of Joseph Grinnell's Museum of Vertebrate Zoology at Berkeley. Why, then, was

[58] Ibid., 77-80, 86-88; On Sumner and his work, see also Francis B. Sumner, "Modern Conceptions of Heredity and Genetic Studies at the Scripps Institution," *Bulletin of the Scripps Institution for Biological Research*, 3 (1917): 2-24; Sumner, "The Value to Mankind of Humanely Conducted Experiments upon Living Animals," *BSIBR*, 6 (1918): 2-27; Sumner, "Heredity, Environment, and Responsibility," *BSIBR*, 10 (1921): 3-12; Charles Manning Child, "Francis Bertody Sumner, 1874-1945," *National Academy of Sciences Biographical Memoirs*, Vol. XXV (1948): 147-173; and William B. Provine, "Francis B. Sumner and the Evolutionary Synthesis," *Studies in History of Biology*, 3 (1979): 211-240.

he able to join the Scripps Institution in 1913? The answer could perhaps be found in Ritter's biological philosophy as outlined above. Sumner above all belonged to the school of natural history and his proposed research was a perfect example of field biology which incorporated some experimental approaches. According to Robert Kohler, Sumner's work on *Peromyscus* was a representative case of borderland biology, as was Ritter's marine biology program as argued above.[59] Moreover, Sumner's genetic ideas differed significantly from the reductionist approaches of the dominant contemporary genetics. In addition, Ritter did not believe in the Darwinian theory of natural selection as the main mechanism of evolution, and he was more inclined to the Lamarckian alternative. It was the theory of inheritance of acquired characters that Sumner's project aimed to prove. Therefore, Sumner's plan fit perfectly with Ritter's widened scheme for the Scripps Institution for Biological Research, and Ritter gladly took all the administrative measures needed to hire Sumner.

Ritter himself spent more and more of his own time working on broader issues of biology. It is apparent that he had been keen on the philosophical aspects of biology for a long time and he frequently wrote and published theoretical articles. With the extension of the administrative burden as the director, however, he had to abandon, somewhat reluctantly, his scientific work and, starting in 1913, spent most of his remaining time on the writing of philosophical manuscripts. Ritter wrote on such extensive topics as evolution, psychology, education, and religion, as well as the philosophical basis of biology. Ritter also shared with E. W. Scripps the progressive ideal that science could and had to benefit humankind and society. For Ritter, particularly, biology and human society could not be separated, and only biology could give true explanations and solutions to social problems. Biologists could provide a scientific basis for psychological matters, social problems, and even religion.

Ritter was also deeply involved in the “Science Service,” which was the eventual outcome of the many years of discussion between him and E.W. Scripps on the scientists’ potential role in the betterment of American society.[60] This enterprise, which originally began as the “Science News Service,” was devoted to informing the public of important scientific ideas in the form of news, and thereby contributing to the

[59] Kohler, *Landscapes and Labscapes*, 199-205, 241-248.
[60] Raitt and Moulton, *Scripps Institution*, 94-95.

enlightening and education of the common American people, and ultimately to democracy and the well-being of society. The organization commissioned scientists to write articles on scientific topics and sold them to newspapers. The Science Service began its business in 1921 and Ritter, as its first President, had to divide his time and energy between the two Scripps enterprises. After his retirement in 1923 from the University of California and the Scripps Institution, Ritter became the full-time President of the Science Service.

The change of the Scripps Institution's direction might have had something to do with the changed atmosphere at Berkeley's Zoology Department. Since the beginning of marine biological study at the University of California, the workers were comprised mainly of the Zoology Department's professors and graduate students whose own research projects were closely related to marine biology. Many of the department's members continued to work actively at the station until around 1910. In other words, the San Diego Marine Biological Association's research program was not only for the Association but also for the Department of Zoology. It was impossible to separate the two institutions both in terms of workers and researches. It was far from exceptional at that time since marine biology was a common interest of most American biologists. The scientific work done as part of the marine station's project was also valuable as work of a university-affiliated biologist. For instance, Alice Robertson's doctoral thesis "Embryology and Embryonic Fission in the Genus Crisia," submitted to the Department of Zoology, for example, was apparently the outcome of her contributions to the marine station's project. She also continued to participate in Ritter's research project in the following years.[61]

Having this in mind, Ritter did not feel the need to hire separate research staff for the station except for a very small number of resident scientists whose work would involve observations and measurements of yearlong phenomena. In 1905, he wrote that

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[61] Alice Robertson, "Embryology and Embryonic Fission in the Genus Crisia," *UCPZ*, 1:3 (1903): 115-156; Robertson, "Non-incrusting Chilostomatous Bryzoa of the West Coast of North America," *UCPZ*, 2:5 (1905): 235-322; Robertson, "The Incrusting Chilostomatous Bryzoa of the West Coast of North America," *UCPZ*, 4:5 (1908): 253-344; and Robertson, "The Cyclostomatous Bryzoa of the West Coast of North America," *UCPZ*, 6:12 (1910): 225-284. Physiological work using marine organisms was also done at the zoology department: Frank W. Bancroft and C.O. Esterly, "A Case of Physiological Polarization in the Ascidian Heart," *UCPZ*, 1:2 (1903): 105-114.

he wanted "an organized, salaried staff" for the Marine Biological Station, but "in most cases occasional visits to the Station for brief periods, with most of the work done elsewhere, would suffice."[62] So the staff could be constituted by "persons in regular positions and with regular incomes in other institutions," most of whom would naturally be the people from Berkeley. Also, "students in the stage of advancement of candidacy for the doctor's degree in a University" could do work at the station. In 1904, for example, professors Ritter, Kofoid, Torrey, and Raymond (physics department), instructor F.W. Bancroft, assistants Alice Robertson, Esterly, and J.F. Bovard as well as several graduate and undergraduate students were listed.

In the early 1910's, however, changes occurred gradually to this pattern of cooperation. Work done at Berkeley tended to move away from marine biology. The zoology faculty, most of whom were once deeply involved in marine biological study, began to spend less and less of their time on marine invertebrates. Most of the graduate students' theses for degrees were not related to marine organisms at all. When marine organisms were used, they were studied in the fashion of "general biology" strictly following the methods of experimental laboratory biology.[63]

The separation of the two institutions and their members becomes evident from the published articles in the *University of California Publications in Zoology* from 1902 to 1920. During the earlier period, 1902-1910, around 66 articles were written by biologists affiliated with the Berkeley's zoology department, out of which 47 were using marine organisms. But in the second period, 1911-1920, out of about 160 articles by the Berkeley biologists only 30 used marine organisms. On the other hand, resident members of the Scripps Institution, not directly affiliated with the zoology department, published almost 60 marine biology articles. From this rough estimate, it is possible to conclude that marine biology no longer constituted the mainstream research at Berkeley.[64] The divergence of biological interests at the Scripps Institution and at the zoology department became so apparent by the late 1910s that the members of the

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[62] Ritter, "General Statement," x-xii.

[63] See for example Myrtle Johnson, "The Control of Pigment Formation in Amphibian Larvae," *UCPZ*, 11:4 (1913): 53-88; and William C. Boeck, "Studies on Giardia microti," *UCPZ*, 19:3 (1919): 89-134.

[64] In the first period, those people who later moved permanently to Scripps are also included in the number of Berkeley biologists, but they are mostly excluded from this number in the second period.

Berkeley campus seldom, if ever, went down to San Diego even during the summers.

What were the factors that brought about the substantially changed interest at Berkeley? Undoubtedly, Ritter's changed status and residency must have played a role. From the summer of 1909, Ritter established a permanent residency at La Jolla at the upper level of the laboratory building.[65] At the same time, he transferred the chair of the zoology department to Kofoid, even though he continued to retain the affiliation with the department. With Ritter, the director of the marine biology station, gone, Berkeley biologists became largely free from his direct influence. Now that the relationship between Ritter and the members of the department naturally became loose, Ritter could not rely on the department as a secure source of manpower for his marine biology program.

The zoology department's change was related to the general transformation that took place at that time in American biology. Seen from a broader perspective, the tendency to move away from marine biology was not confined to the Berkeley biologists. During the 1910s, marine organisms gradually lost their merit for most biologists. The marine invertebrates were certainly the best subject of study for some time especially in the study of embryology, development, and evolution. In the 1890's and 1900's, biologists' understanding of fundamental problems such as heredity, development, reproduction, and evolution was meager, and all these branches of life science were in an intermingled state. Thus, the work of embryologists, cytologists, geneticists, and physiologists were not far from one another, and they were, in fact, pursuing slightly different aspects of a larger problem. Marine organisms provided the biologists with the best chances to attack problems since they offered several advantages—they were easy to obtain, they had simple and primitive structure and organization, and they were easy to manipulate with laboratory techniques. By the mid-1910's, however, biology became much more specialized and diversified as a result of the biologists' accumulated researches. Various specific fields such as genetics, cytology, embryology, animal behavior, psychology, eugenics, and paleontology began to emerge as focused domains. Specialized and more professionalized biology lost its interest in the marine organisms generally for the biologists were now prepared to work on more complicated animals or

[65] Raitt and Moulton, *Scripps Institution*, 54.

various other kinds of animals that were better suited for specialized research.[66]

Many historians of biology have paid attention to the development of biology at this period. Adele Clarke, for example, showed that the process of specialization took place in the early twentieth century. Biologists in the United States had conducted research in the vaguely defined field of "heredity-evolution-reproduction-development." in the earlier period.[67] But as biologists came to know more and more about these life phenomena, specialized branch sciences emerged, a process which Clarke called the "three-way split." With clarified concepts and improved experimental tools, researchers began to engage themselves in more specific lines of study—genetics, development embryology and reproductive science. The zoology department at Berkeley was no exception to this larger change going on at the national level. The department certainly belonged to the American biologists' community and its members were all connected in some ways to other biologists throughout the country. They were well aware of the changes taking place and sought to keep pace with them. Work at the Scripps Institution was, therefore, not as important to the people at Berkeley as before. Ritter's widened vision for the Scripps Institution also might have been a result of his realization that marine biology alone was no longer sufficient as a central research theme in the new era of American biology.

The Marine Biology Program, espoused by Ritter, largely lost its central position at the Scripps Institution by the late 1910's. Attenuation of marine biological research at La Jolla also had to do with the loss of its main workers. Four men were particularly prominent in the study of marine biology, pursuing the thorough and comprehensive understanding of marine organisms by the combined methods of systematics, morphology, physiology and ecology. They were Charles Kofoid, Harry B. Torrey, Calvin Esterly, and Ellis Michael. They were the main forces leading the Institution's plankton research. In the 1910's, however, the Institution actually lost three of them.

Charles Kofoid and Harry Torrey were Ritter's closest helpers and strongest advocates during the founding stage of the station. Kofoid's interest in planktons began

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[66] See, for example, Pauly, *Biologists and the Promise of American Life*, 145-164.

[67] Keith Benson, Jane Maienschein and Ronald Rainger, eds., *The Expansion of American Biology* (New Brunswick and London: Rutgers University Press, 1991). See, especially, Adele E. Clarke, "Embryology and the Rise of American Reproductive Sciences, circa 1910-1940," in this volume, 108-109.

long before he came to California. After receiving his Ph.D at Harvard, he was engaged in the study of planktonic animals of the Illinois River as a faculty member of the University of Illinois. Particularly, his work there involved an extensive use of statistical and mathematical methods as well as various field techniques. As a matter of course, he became the main source of influence on Ritter's idea of ecological and statistical marine biology.[68] Kofoid's experience at the Illinois River Survey enabled him to be the main designer of the San Diego Marine Biological Association's laboratory facilities and its research vessels. He also participated in the designing of its aquarium, devised the Kofoid collecting net, and purchased laboratory instruments during his visit to Europe.[69] In the 1910's, however, he began to lose his longtime interest in planktons. Although he still retained the official title of Assistant Director of the Scripps Institution for Biological Research, his burden as the zoology department's chair made it difficult for him to participate actively in the affairs at La Jolla. His new research topics also made it unnecessary for him to make frequent visits to La Jolla. Kofoid's interest in microscopic animals gradually led him to a brand new domain, the study of protozoa and parasitology.[70] Beginning in the late 1900's he embarked on parasitological study with his students, such as Olive Swezy, Irene McCulloch, and Elizabeth Christiansen, and the results of their work began to be published in 1909.[71] Their work on parasites dealt with diverse subjects, such as life history, reproduction of unicellular organisms by mitosis, cytology, genetics, morphology, and embryology. Even though he did not totally abandon the dinoflagellata project, marine biology hardly occupied the central place in Kofoid's work.

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68 Pauly, *Biologists and the Promise of American Life*, 203-207.

69 Charles Kofoid, "On a Self-closing Plankton Net for Horizontal Towing," *UCPZ*, 8: 8 (1911): 311-348; Kofoid, "On an Improved Form of Self-closing Water-bucket for Plankton Investigation," *UCPZ*, 8:9 (1911): 353-357; Kofoid, *The Biological Stations of Europe* (Washington, D.C.: Government Printing Office, 1910).

70 Goldschmidt, "Charles Atwood Kofoid," 121-151.

71 For example, Edward Hindle, "The Life History of Trypanosoma dimorphon Dutton and Todd," *UCPZ*, 6:6 (1909): 127-144; Irene McCulloch, "An Outline of the Morphology and Life History of Crithidia leptocoridis, sp. nov.," *UCPZ*, 16:1 (1915): 1-22; Charles Kofoid and Elizabeth Christiansen, "On Giardia microti sp. nov., from the Meadow Mouse," *UCPZ*, 16:2 (1915): 23-29; and Kofoid and Christiansen, "On Binary and Multiple Fission in Giardia muris (Grassi)," *UCPZ*, 16:3 (1915): 30-54. In addition, there are about 26 more articles published by Kofoid's parasitology group in the *UCPZ* until 1920. It is noteworthy to mention that most members of this group were women.

Harry Beal Torrey, the ardent researcher of marine biology at Berkeley, left the University in 1912. From the beginning of his career in biology, he was deeply engaged in Ritter's marine biology enterprise. He was, particularly, responsible for assembling and arranging the books for the marine station's library. Torrey joined Berkeley's zoology faculty in 1895 and was, with Kofoid, the major collaborator of Ritter in building the marine biological station. He went to Reed College in Oregon to become the first zoology professor and remained there until 1920. After that, he also taught at the University of Oregon and Stanford University.[72] It is not clear whether his interest in marine biology lasted after he left Berkeley, but he certainly was disconnected from Ritter's marine station with his departure to Oregon.

Ellis Michael's early death in August, 1920 was the fatal blow to the marine biology program at the Scripps Institution.[73] Michael, who was a resident worker at the station, conducted the plankton study most thoroughly. As he was working at the station full time, his time was entirely devoted to marine biological study. Working at the station for fifteen years, his philosophical point of view most closely resembled Ritter's concept of marine biology and his actual scientific work was truly a model of the "marine biology" at the Scripps Institution. Collaborating with McEwen, his plankton study incorporated physical conditions of the sea most successfully. And he believed in the ideal of combining field and laboratory work. In 1920, he went on a research trip to the Bahamas and the Panama Canal on *Kemah*, E.W. Scripps' yacht. After the three-month trip, he became ill and died at the age of thirty nine. He was the main worker in marine biology at the Institution throughout the 1910s, and his death virtually marked the end of Ritter's marine biology program.

The marine biology program at the San Diego Marine Biological Association, and later at the Scripps Institution, which was articulated by Ritter and pursued by a small group of biological scientists under the leadership of Ritter, came to an end around 1920 with the death of Ellis Michael. As we have seen, the program had already lost its dominant position at the Institution when Ritter himself modified, if not abandoned, the original aim of the Institution in 1912. Although Esterly continued his part of the plankton research, he was a summertime worker at the Institution, not directly connected

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[72] For Torrey's career and his scientific work, see the *Harry Beal Torrey Papers*, The Bancroft Library, University of California, Berkeley.
[73] Raitt and Moulton, *Scripps Institution*, 82.

to the University. In the last few years of Ritter's directorship, marine biology still occupied an important part of the Institution's research. Yet, it no longer was the original Ritterian "marine biology."

5. Towards Oceanography: Unexpected Growth of the Physical Sciences

From the beginning of the University of California's marine biology project, physical study of the ocean was an indispensable part of the research program. Ritter openly pronounced his belief that physical, chemical, and geological properties of the ocean needed to be studied along with biological work. It was especially true for the study of the Pacific Coast since this part of the sea was a totally new and unknown region for American scientists. As his idea of marine biology emphasized the incorporation of the role of the marine environment, physical information was in fact indispensable. He actually included at least one physical scientist in his group whenever he went to the sea with his fellow biologists. His strong assertion was, however, more often a strategy to arouse his potential supporters' and patrons' interest in his project rather than an expression of his actual plan to make it a separate branch of research at his marine biological station. For him, physical and chemical knowledge of the sea was needed only to the degree of being able to support biological studies. The kind of information biologists needed was all he wanted, and Ritter felt no need for a physical oceanography program for its own sake, especially when the station's budget was barely enough for the biological projects.[74]

It was exactly in this context that Ritter decided to hire George McEwen, first as a part-time worker and later as a full-time staff member. McEwen, who was a physics graduate student at Stanford, became interested in geophysics and hydrodynamics, and began to work at the San Diego station in 1908 as a part-time worker. Aware of his excellent ability and skills in physical measurement and mathematical calculation, Ritter

[74] Michael, "Dependence of marine biology," i-xxiii. Several articles in the volumes 9 (1911-1012) and 15 (1915-1916) of the *UCPZ* written by Michael, McEwen, and Ritter dealt directly with physical data.

thought that having him among his staff would greatly benefit his marine biologists. Since McEwen would be able to do the various kinds of work at the station that biologists were not trained to do, he was expected to be "useful in many capacities."[75] And McEwen's usefulness was actually proven when he carried out successful cooperative work with Ellis Michael and other biologists. As a permanent researcher at the Marine Biological Association since 1911, he accumulated the data of daily, monthly, seasonal, and yearly changes of ocean temperature, salinity and density. Using the methods recently developed by Vilhelm Bjerknes and his followers in Northern Europe, he was also able to analyze the movements of the seawater. The data provided by McEwen were useful to ecological marine biology, and his gathering and interpreting of the physical information were done according to the needs of the plankton researchers. Ritter was certainly satisfied.[76]

Doing his assigned job of helping and cooperating with the marine biologists at the station, McEwen was also able to carry out his own research at the same time. The importance of his physical study was soon realized by Ritter and others, and it did not take long for Ritter to arrive at the idea that physical oceanography was in itself worthwhile as an independent branch of marine science. What impressed Ritter even more was the practical usefulness of McEwen's physical study. McEwen became interested in the interaction between the sea and the atmosphere, and he thought that the physical properties of the surface seawater might influence the weather. A close look at the available past data convinced him that there surely was an intimate correlation between the surface temperature of the coastal sea water and the time and amount of rainfall in California. Confident of his theory, he set out to devise a method to make long-term weather forecasts and was, in fact, able to make some weather reports that worked quite well.[77] If McEwen's work would continue to work well, it would bring about incalculable benefits to the various industries of California. The prospect of this project made Ritter especially excited, for benefiting society with science was his long-

[75] Eric L. Mills, "Useful in Many Capacities: An Early Career in American Physical Oceanography," *Historical Studies in the Physical and Biological Sciences*, 20 (1990): 265-311.
[76] George F. McEwen, "Hydrographic, Plankton, and Dredging Records of the Scripps Institution for Biological Research of the University of California," *UCPZ* 15:2 (1915): 207-254.
[77] George F. McEwen, "The Distribution of Temperatures and Salinities, and the Circulation in the North Pacific Ocean," *BSIBR*, 9 (1919): 58-64; McEwen, "Oceanic Circulation and Its Bearing upon Attempts to Make Seasonal Weather Forecasts," *BSIBR*, 7 (1918): 3-20.

held ideal.

With Ritter's approval, McEwen's physical research came to form a part of the Scripps Institution's scientific activities, although he continued to work with Michael and Esterly. No one expected this outcome. Both before and after the official name change, the institution had always been devoted to biology. Existence of a physical scientist at a marine biological institution was understandable so far as he would play an auxiliary role. However, it was extraordinary to see an independent physical oceanography program at a scientific institution "for Biological Research." Even though Ritter had proclaimed that his institution would have a broader aim, it was apparently confined to biology. This unexpected development of the physical science program at the Institution tells us something about the character of Ritter's scientific leadership. He, and E. W. Scripps, was more interested in contributing to the welfare of the society through the scientific work of the institution than maintaining a focused research program there. Whether a new line of research proposed by a staff member fit well into the overall aim of the institution was only a secondary consideration for Ritter.

By the time the Scripps Institution got involved in World War I, then, its character was quite vague. It was a biological institution which had its origin in a marine biological station, which still had marine biological researches going on. However, its scientific activity was no longer confined to marine biology. Director Ritter's biological philosophy and Francis Sumner's mice experiments were also supported. Moreover, McEwen was conducting his work on physical oceanography and meteorology. It was, thus, a rare combination of distinctively different scientific researches that characterized the institution. What, then, could the Scripps Institution do to take a part in the national war efforts? What were the things that the institution was could do especially well?

The Scripps Institution's wartime work was mainly related to food production.[78] Particularly, researches on kelp and fisheries were conducted at the Institution during the war years. The U.S. Government was interested in the potential production of fertilizers out of kelp, and at the Institution, W.C. Crandall was an expert on kelp with years of experience. Long before the war, since 1911, he had studied kelp on the California coast for the U.S. Department of Agriculture. As a special agent for the U.S. Bureau of Soils,

[78] See, for example, Ritter, "The Resources of the North Pacific Ocean: Their Extent, Utilization and Conservation," *BSIBR*, 5 (1918): 3-20.

he surveyed the marine plant and studied the possibility of making kelp fertilizers. During the war, his main duty was to advise the State Game and Fish Commission about the availability of the kelp beds for harvesting. To know when and where the kelp could be harvested, Crandall had to conduct close investigations on the plant's growth rate, life cycle, and susceptibility to various diseases.[79]

More staff members of the Scripps Institution were involved in the fisheries research. Ritter was the Director of Operations for the U.S. Bureau of Fisheries in southern California and Crandall was the National Food Administration's Fish Administrator for southern California. Other researchers of the Institution were also involved in the investigation of the geographic distribution of tuna, experiments on the various fish preservation methods, study of planktons as a food source for fish, and the hydrography of certain areas of the sea which constituted the living environment of fish populations. These researches were aimed at increasing the catch of fish and, eventually, expected to contribute to the increased food supply for the country at war. The Scripps Institution proved very useful in the war effort since it was the only research-oriented scientific institution that could conduct various organized researches on projects related to the sea. Despite its other research interests, the Institution's usefulness derived from its old-time specialty of marine biology and related physical studies.[80]

The wartime experience of the Scripps Institution greatly influenced both Ritter's thoughts and the future of the institution. First, Ritter realized his institution's unique position in the whole country. Despite its name, "The Scripps Institution for Biological Research," it was in fact the only research institution in the United States that possessed the facilities and manpower to conduct researches in marine sciences. Ritter's re-discovery of the institution's unique ability eventually led him to the decision to turn it into an oceanographic institution after his retirement. The war work reminded him of the insufficiency of knowledge about the Pacific Ocean, and taught him that it was worthwhile to do more study of the sea and its resources. That was what the Scripps Institution could do best to contribute to the whole society.[81]

The other changes that the war brought to the Institution were its new relationship with various government agencies and its involvement in government-

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[79] Raitt and Moulton, *Scripps Institution*, 90-95.
[80] Ibid.
[81] Ritter, "The Resources of the North Pacific Ocean."

related activities. The wartime work was done in connection to such diverse government agencies as the U.S. Bureau of Fisheries, the U.S. Bureau of Chemistry, the Federal Food Administration, and several state agencies.[82] The relationship lasted after the war and affected the institution's development considerably. One effect was that the Scripps Institution could use the ships and facilities of these agencies and that the observation and measurement data they gathered became available to the Institution's researchers. The close relationship and cooperation with the U.S. Navy, the U.S. Coast and Geodetic Survey, and the U.S. lighthouses were particularly important in this respect. The Scripps Institution's decision in 1917 to sell its research vessel *Alexander Agassiz* can be understood in that context.[83] Although Ritter reported to the President of the University that it was "too large and expensive to operate for the particular phase of the marine investigation [that the institution was] entering upon," economic and management problems were certainly not the main reason for the selling. Had the government facilities not been available, the Institution probably could not have done without its own vessel, *Alexander Agassiz*. How could the researchers like McEwen and Michael continue their work without a boat? It was only because they had access to the government ships that they began to feel that the retaining of their own vessel was burdensome.

In 1919, the Pacific Exploration Committee was formed by the National Research Council, where Ritter and McEwen became members. Also, in 1921, the Committee on Conservation of Marine Life of the Pacific was organized by the Pacific Division of the American Association for the Advancement of Science. W.C. Crandall was one of its five members, and both he and P.S. Barnhart, curator of the Scripps Institution's aquarium, participated in its programs. All these reflected the renewed national interest in the sea, particularly the Pacific Ocean. And, as the members of the Institution actively took part in these organizations and others, its image as an institution devoted to marine sciences consolidated.[84] The staff members, too, came to possess the belief that their institution was a place for marine biology, or oceanography, rather than biology in general.

It has been an old question why the Scripps Institution suddenly turned its

[82] Raitt and Moulton, *Scripps Institution*, 90-95.
[83] Ibid., 91.
[84] Ibid., 92-95.

direction to oceanography, and eventually changed its name to "The Scripps Institution of Oceanography." The change was often attributed to the choice of the second director of the institution, T. Wayland Vaughan, who was a marine geologist. Yet, it is clear from Ritter's, and Vaughan's, words that the decision was made before Vaughan was even considered as a candidate. "For some reason, which I do not know," Vaughan remarked for instance, "it was decided before Dr. W. E. Ritter's retirement from the directorship of the Scripps Institution of Biological Research [*sic*], to convert the institution into one for oceanographic research."[85] The fact is, then, that it was not Vaughan who influenced the decision but, on the contrary, it was the decision made earlier that affected the selection of Vaughan as the second director of the Institution. As I have indicated, it is reasonable to think that the decision resulted from the Scripps Institution's wartime experience, and partly from the impressive job McEwen had done.

This passage tells us not only about the decision to make the institution oceanographic, but also about the concept of oceanography held by Ritter. To Ritter, the term oceanography had a somewhat different meaning from what we perceive today. He used the word without giving it a definition and, therefore, its meaning was often unclear. But he usually used it in the sense of physical studies of the ocean, along with hydrography. So, in Ritter's terminology, the word oceanography usually did not include biological studies of the ocean. In some places, especially in later years, oceanography seemed to include biology, too. Renaming his institution, then, did not mean excluding biology entirely from its program. Yet, it certainly implies that the institution would not be devoted solely to biological researches. At the renamed institution, biological and physical studies would be combined on equal status. What Ritter wanted was that the institution contribute to "the idea of interconnection of biology and oceanography" (here, in the sense of physical study), just as the Science Service would later contribute to "the idea of interconnection of biology and sociology."[86]

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[85] T. Wayland Vaughan, "Response of the Medalist," *Science*, Vol. 83, No. 2160 (May 22, 1936): 475-477.
[86] Ritter, "The Name, "Scripps Institution of Oceanography,"" *Science*, Vol. 84, No. 2169 (July 24, 1936): 83.

6. Conclusion

The research program Ritter designed for his seaside institution failed to survive throughout his directorship. This was mainly because Ritter himself lacked consistency. He widened the scope of the institution in the early 1910's to include non-marine biology such as Sumner's. Even though marine biological study did not disappear, it was not the central work of the institution by the late 1910's. Sumner's *Peromyscus* research and McEwen's physical and meteorological work became as prominent as marine biology. By the time Ritter was to retire, the direction of the Scripps Institution's research was extremely unclear. One can hardly conclude, then, that Ritter's marine biology program was a success. Perhaps it just reflected his scientific and philosophical ideas at a certain period of his life, and these were bound to change later.

One can never deny, however, the fact that the program was truly unique and that the San Diego Marine Biological Association was the only research institution at that time that actually carried out such a program. Although it eventually proved to be unsuccessful, the peculiarity of the program largely determined the institution's future development. Among so many marine biology stations, the Scripps Institution was probably the only one that developed into an oceanographic institute. Without taking Ritter's marine biology program into consideration, it is impossible to understand this development. There were several aspects within the program that enabled the transformation. First, Ritter's marine biology espoused the idea that everything in the ocean is interconnected. The program aimed at understanding the parts and their correlations in order to get at the knowledge of the ocean as a whole. It is true that the program originally was confined largely to biological phenomena. But when it was slightly modified, it could easily turn into a program for oceanography, the aim of which was to arrive at the understanding of all of the natural phenomena of the ocean. Second, the program of marine biology emphasized the role of the physical, chemical and geological environment of marine organisms from the beginning. Initially given a subordinate role, physical oceanography soon became an important part of work at the station. Particularly because of McEwen's work and the World War I experience, Ritter and others gradually realized that the physical aspects of the ocean were worthy of study independently from biology. In most other marine biology stations, the idea of collaboration with physical scientists hardly existed, and this aspect of the marine biology program eventually led the institution in an oceanographic direction. Finally, the program emphasized the importance of field work. Marine biology had to be a field science, and scientists at the station had to go out to the sea frequently. This tradition enabled its members to get used to the sea and working on board ships. Had the institution and its program emphasized laboratory work instead, the transformation towards oceanography could not have happened.

Of course, the oceanographic aspects of the marine biology program were not in themselves sufficient for the actual change to take place. Political, economic, and personal factors worked together to change the Scripps Institution. Also, Ritter's concept of oceanography as well as the overall work at the institution in the early 1920's was far from truly oceanographic. Ritter's idea of oceanography still emphasized biological study. In that sense, much had to be done to make it into a really oceanographic institution in spite of the already decided name change. It was T. Wayland Vaughan who would carry out the task of remaking the institution.

CHAPTER 3
From Biology to Oceanography: T. Wayland Vaughan and Oceanography at the Scripps Institution

Throughout more than twenty years of William E. Ritter's directorship, the Scripps Institution continued to be a place for biological research—be it marine or not. Taxonomy, biogeography, ecology, and physiology of marine organisms were studied at the station along with study of the physical marine environment. Francis B. Sumner, on the other hand, was conducting a breeding experiment of field mice, *Peromyscus*, at the station to establish his own theory of evolution and genetics. Although George McEwen's physical work on hydrography and meteorology gained more and more importance in the 1910's and early 1920's, biology was still at the center of the institution's program of research. This was due primarily to director Ritter's background and interest in things biological. Having been trained in the old school of naturalist biologists, he retained the goal of making his institution at La Jolla the Mecca of biological field sciences.

This all changed with the coming of Thomas Wayland Vaughan to the Scripps Institution as its second director with the mission to make it oceanographic. As a marine geologist, Vaughan approached oceanography from a very different perspective from that of Ritter. To him, marine biology was no more than one of the several branches that made up the science of oceanography, whereas it was the core part of the Scripps Institution's program for Ritter. The Scripps Institution had its origin in the summer camp of the University of California's department of zoology, and had long been considered primarily as a biological institute by people both within and outside the institution. Vaughan's task, therefore, involved a break from the institution's own past in order for it to transform into a truly oceanographic institution.

The task was a difficult one since there was no previous model to emulate. The Scripps Institution was the first oceanographic institution established in the United States. Moreover, transformation of a marine biological station into a thoroughly oceanographic one had hardly ever happened even in Europe. Therefore, Vaughan had to make every decision by himself in reconstructing the Scripps Institution. He had the advantage of being able to use the resources that already existed at Scripps but, at the same time, changing the existing order was often more difficult than establishing a wholly new institution. Organization of the institution, its relationship with other branches of the university, and the role of the institution within the university system all had to be changed completely.

The new Scripps Institution that resulted from Vaughan's reform, thus, reflected his scientific ideas, administrative practices, personal preferences and experience. Considering the Scripps Institution's place in history as the first American oceanographic institution, especially in the first half of the twentieth century, and Vaughan's personal role in its development, tracing his ideas and the process of the institution's transformation is indispensable in understanding oceanography's past. This chapter will show how Vaughan's idea of oceanography formed the blueprint of the new Scripps Institution of Oceanography and what he endeavored to do to restructure the biological institution, particularly in the first few years of his directorship.

1. "The Name, Scripps Institution of Oceanography"

T. Wayland Vaughan became the Scripps Institution's second director in 1924. In the next year, the institution's name was officially changed from the "Scripps Institution for Biological Research" to the "Scripps Institution of Oceanography." It has often been misunderstood that Vaughan was responsible for this name change as well as for the institution's transformation from a biological station to an oceanographic institution. Scripps under Vaughan's directorship was very different from what it used to be with Ritter and many people naturally attributed the metamorphosis to the new director. It should be noted, however, that the decision to make the institution oceanographic and to change its official name was made earlier by William Ritter and the Regents of the University of California. In 1936, when receiving the National Academy's Agassiz Medal in Oceanography, Vaughan remarked:

> For some reason, which I do not know, it was decided before Dr. W. E. Ritter's retirement from the directorship of the "Scripps Institution of Biological Research [*sic*]," to convert the institution into one for oceanographic research. In 1923 I was offered the directorship of the institution, and its name was changed on October 25, 1925, from "Scripps Institution for Biological Research" to "Scripps Institution of Oceanography." Therefore the Scripps Institution of Oceanography was the first institution in the United States that had for its major purpose the prosecution of research on the ocean.[1]

Here, Vaughan made it clear that he had not participated in the earlier discussions on the Scripps Institution's new policy and did not know the reasons for the decision.

In answer to Vaughan's remark, Ritter wrote a short article, "The Name, "Scripps Institution of Oceanography,"" in *Science* only two months later.[2] He began by admitting that his frequent mention of the institution's name made many people, including Vaughan, "more hazy than, as I now see, it should be." Ritter's intention behind the new name of his institution was not simple, though. There was an important implication which he shared with Edward W. Scripps, among others, from earlier times. Scripps once discussed with Ritter his idea of founding a "department of sociology" within the Scripps Institution, which reflected his firm belief that "any such separation between biology and sociology as [had] recently come to be assumed" was problematic.[3] For practical reasons, the Scripps Institution for Biological Research remained a natural science institute and the proposed sociology department was later founded at the Miami University at Oxford, Ohio, but the "idea of interconnection of biology and sociology" was never abandoned by Ritter and E. W. Scripps. Scripps was interested in population problems and thought that the subject could best be studied by the workers of biology

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[1] T. Wayland Vaughan, "Response of the Medalist," *Science*, Vol. 83, No. 2160 (May 22, 1936): 475-477.

[2] William E. Ritter, "The Name, "Scripps Institution of Oceanography,"" *Science*, Vol. 84, No. 2169 (July 24, 1936): 83.

[3] Philip J. Pauly discusses Ritter and E. W. Scripps' ideas on the role of science in society in *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey* (Princeton: Princeton University Press, 2000), 201-213.

and sociology together.

In a similar vein, Ritter wished to see the "idea of interconnection of biology and oceanography" materialized and bear fruit at the Scripps Institution. According to his "organismal conception of life" all life phenomena are interconnected and, likewise, everything in the sea is interrelated. His holistic point of view directed him to think that in order to understand the ocean properly, it had to be viewed not in parts but as a whole.[4] Ritter came to understand that physical characteristics of the sea could not be bypassed in the study of marine biology as the life patterns of marine organisms are greatly influenced by them. Purely biological study of marine biology could never produce a perfect understanding of the total life phenomena of the ocean unless the physical properties were taken into account. Ritter was aware of this close relationship between marine biology and physical oceanography from the very beginning. He always accompanied physical scientists in his marine biological surveys, and encouraged collaboration between biologists and physical oceanographers. Emphasis had always been on the side of biology, however. Ritter's enterprise had always been biological, from the zoology department's summer camp to the San Diego Marine Biological Association, and finally to the Scripps Institution for Biological Research. George F. McEwen, physical scientist of the institution since 1908, was primarily expected to assist the marine biologists.[5]

The change of the institution's name implied, therefore, modifying this one-sided relationship between marine biology and physical oceanography. Ritter quoted from his letter to E. W. Scripps of August 28, 1922, where he had mentioned what type of institution Scripps should become: "That type can now be pretty definitely expressed by the suggestion that in the future the Scripps Institution should become more exclusively . . . an institution of oceanography (both biological and physical oceanography)."[6] Ritter must have thought that the task of amending the unequal relationship might best be accomplished by adopting the term oceanography, which includes within itself both physical and biological oceanography. By renaming the

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[4] William E. Ritter, *The Unity of the Organism, or the Organismal Conception of Life*, 2 vols. (Boston: Richard G. Badger, The Gorham Press, 1919).

[5] On George McEwen's work at Scripps, see Eric L. Mills, "Useful in Many Capacities. An Early Career in American Physical Oceanography," *Historical Studies in the Physical and Biological Sciences*, 20 (1990): 265-311.

[6] Ritter, "The Name."

Scripps Institution, Ritter and his patrons intended to raise the status of physical oceanography up to that of marine biology and make the relationship between the two interconnected fields more balanced and, thereby, more productive.[7] In sum, his overall intention was to make the scientific work of the institution more "organismal" than before, emphasizing the holistic feature of not only the marine life phenomena but the whole natural phenomena of the ocean.

The task of realizing the "idea of interconnection of biology and oceanography" at the Scripps Institution could not be carried out by Ritter himself as his retiring time was drawing near. He, therefore, had to search for someone suited for this challenging job of building the first American oceanographic institute. It is clear from the following passage what kind of person Ritter and the University of California were looking for:

> The recommendation is that the new director be selected with sole reference to the work upon the ocean and its life and that as rapidly as may be without harm to any of the investigations now in progress, the program be made exclusively oceanographic, the understanding to be that both the biology and the physics (physics being understood to include every aspect of the ocean as such) be included in the program on an equal footing. The suggestion is that an Institute of Oceanography be aimed at that shall finally have a scope and character worthy of the Pacific, the greatest of the oceans; and worthy also of the greatness of the United States as a nation and of the State of California.[8]

Ritter wanted his successor to be familiar with the study of the sea and to know something about both biological and physical oceanography, particularly of the Pacific Ocean. He also had to understand the meaning and value of the scientific work that had been undertaken at the institution until that time. It was difficult to find such men in the United States at the time because oceanography was not yet established as a scientific

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[7] Ritter did not use the term "oceanography" in a consistent way. He often mentioned oceanography as a synonym for "physical oceanography" or "hydrography," whereas at other times he used it as a more comprehensive term including both physical and biological studies of the sea.

[8] "A Proposed American Institute of Oceanography," *Science*, Vol. 58, No. 1490 (July 20, 1923): 44-45.

field in the country and only a very small number of scientists could be called oceanographers. The first choice was Henry Bigelow of the Museum of Comparative Zoology at Harvard University but he declined the offer because of some family reasons.[9] T. Wayland Vaughan, who had had earlier contacts with Ritter and other Scripps staff members at the meetings of the Committee on Pacific Investigation of the National Research Council, was then selected as the best person for the position. It can, therefore, be said that Vaughan's task was already laid out for him by Ritter, although its meaning was not so clear.

2. T. Wayland Vaughan, Oceanographer

Thomas Wayland Vaughan was born in Jonesville, Texas in 1870.[10] His father, Dr. Samuel Vaughan, was a wealthy country physician. Vaughan was educated in local public schools and by private tutors and in 1885 entered Tulane University, where he majored in physics. He initially wanted to pursue a medical career, but as he became interested in electricity and its application he then studied in the "Physical Science Course" instead. Although his major was in the physical sciences, Vaughan studied broadly; he was interested in philosophy, literature, and the problem of evolution and fossils. From 1889 to 1892, Vaughan taught physics and chemistry at a junior college in Mount Lebanon, Louisiana, where he became fascinated with geology and paleontology and eventually decided to devote his life to the study of the earth. Vaughan made his first extensive fossil collection, which included mollusks and corals, in Mount Lebanon, and in the summer of 1892, served as assistant to Dr. Otto Lerch, State Geologist of Louisiana.

Having made up his mind to become a professional paleontologist, Vaughan went to Harvard University in 1892, where he had already taken a course in botany in

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[9] Helen Raitt and Beatrice Moulton, *Scripps Institution of Oceanography: First Fifty Years* (San Diego: Ward Ritchie, 1967), 96.

[10] Thomas G. Thompson, "Thomas Wayland Vaughan," *National Academy of Sciences Biographical Memoir*, 32 (1958): 398-437.

the summer of 1890, to take "all the lower division courses in biology, all the courses in paleontology, and several courses in geology."[11] Vaughan received a Bachelor of Arts degree from Harvard in 1893, and a Master of Arts degree in the next year. Vaughan's career with the U.S. Geological Survey began in 1894, when he was enrolled at Harvard as a nonresident Ph.D. student. He worked for the U.S. Geological Survey as assistant geologist and, in 1897, he had a chance to stay in Europe as a delegate to the International Geological Congress in Russia. Vaughan received his Ph.D. degree from Harvard in 1903 with a dissertation titled "Eocene and Oligocene Corals of the United States."

While working for the Geological Survey, Vaughan conducted several successful projects in places such as the West Indies, the Panama Canal Zone, the Virgin Islands, Puerto Rico, and the Gulf Coast Plains from Cape Cod to the Mexican Border, which brought him fame especially among Washington D.C.'s scientific circle.[12] He became widely known as an expert particularly in the study of coral reefs. Since many of the projects that he was engaged in were done in connection with other institutions such as the Smithsonian Institution, the Carnegie Institution of Washington, and the U.S. Navy, as well as several State Geological Surveys, Vaughan could build and maintain strong ties to them, which later turned out to be a great asset as director of the Scripps Institution.

By the time he went to La Jolla, Vaughan was among the very few people in the United States who could be called an ocean scientist. In addition to the fact that he was an expert in marine geology and paleontology, Vaughan was also deeply interested in the science of oceanography. It began perhaps with his acquaintance with Alexander Agassiz, the father of American oceanography. In the early 1890's, when Vaughan was still a graduate student at Harvard, Agassiz asked him to "help him with the identification of some of the corals that he had collected in his expeditions in Florida and the West Indies" and, sharing the interest in the organism, they continued the close relationship until Agassiz's death in 1910.[13]

Influences from European oceanographers also played some role in shaping

[11] Ibid., 401.
[12] Ibid., 401-403.
[13] T. Wayland Vaughan, "Response of the Medalist," *Science*, Vol. 83, No. 2160 (May 22, 1936): 475-477.

Vaughan's ideas about oceanography. Vaughan knew Sir John Murray, a renowned British oceanographer, very well. He first met Murray in 1897 at the International Geological Congress in Russia. The relationship with Murray lasted until his death in 1914. This prominent oceanographer, who had participated in the *Challenger* Expedition, must have been a major source of inspiration for Vaughan on oceanographic issues.[14] Especially in 1911, when he came to the United States to deliver a memorial address on Alexander Agassiz in Cambridge, Murray spent several months in Washington and Vaughan met him "almost every day." During his stay in the United States, Murray tried to arouse among American scientists interest in oceanography, and wanted, in particular, to encourage the Americans to begin the study of "the west side of the North Atlantic which would conform in method and be contemporaneous with the investigations that were being conducted on the east side of the North Atlantic under the auspices of the International Council for the Exploration of the Sea and with the work of such distinguished Norwegians as Helland-Hansen, Fridtjof Nansen and others."[15]

Vaughan was among the "group of 25 or 30 scientific men interested in oceanography" who invited Nansen to a dinner at the Cosmos Club in January, 1918 during his visit to Washington.[16] Nansen emphasized the need for "the intensive study of oceanic circulation" in the United States. According to Vaughan, the efforts of Murray and Nansen did not bring about immediate results. However, their influence continued among the small group of Americans and would later prove instrumental in the development of oceanography in the United States.

Since he was a graduate student, therefore, Vaughan had constantly been exposed to the influences of prominent American and European ocean scientists and became deeply sympathetic to their claims on the need for a program of oceanographic research in the United States. Therefore, it was no coincidence that Vaughan came to Ritter's mind as the best candidate for the Scripps Institution's directorship when he was hunting for an appropriate person to succeed his enterprise and accomplish the mission of building the first American oceanographic institution.

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[14] Ibid.; Thompson, "Thomas Wayland Vaughan," 401.
[15] Vaughan, "Response."
[16] Ibid.

3. Oceanography as Earth science: Vaughan's Concept of Oceanography

Soon after coming to the Scripps Institution for Biological Research as its second director, Vaughan clarified his understanding of oceanography in a document in which he openly proclaimed his policy on the institution's operation. Vaughan's concept of oceanography significantly differed from that of Ritter and, thus, that document suggested that the institution's program of research would look very different under the new director. Vaughan's definition of oceanography clearly showed the strong influence from his background in geology. He understood the science of the ocean from the perspective of an earth scientist. Vaughan thought that

> Oceanography, as its name implies, is the study of the ocean. . . . [T]he ocean must be considered in its relations to the other materials which collectively constitute the earth—that is oceanography is one of the earth sciences and needs to be considered in its relations to all the other earth sciences.[17]

To geologist Vaughan, oceanography was a part of earth science since the ocean constituted a part of the earth. Hence, his approach quite naturally emphasized the relationship between the sea and the other parts of the earth. It was a typical way of thinking for most geological scientists as they had long been aware of the close relationship between the geological phenomena taking place under the sea and on land.

It did not mean, however, that Vaughan thought geology of the sea to be equal to the whole of oceanography, or that marine geology, or geological oceanography, was the most important part of oceanography. He believed, instead, that in order to understand the ocean fully, every aspect of the sea had to be studied by experts in each field. That is, physics, chemistry, biology, and geology of the ocean all had to be studied on an equal

[17] T. Wayland Vaughan, "The Scripps Institution—Its Present Work in Oceanography and Suggestions for Its Future Development" (1924), Records of the SIO Office of the Director (Vaughan), 1924-1936, Scripps Institution of Oceanography Archives, University of California, San Diego.

footing.

> Oceanography is not a science within itself, but depends upon the fundamental sciences of physics, chemistry, and biology for the interpretation of the phenomena exhibited by and within it and associated with it. The ocean, therefore, may be looked at in several ways, and for convenience I am recognizing in oceanography four branches, which are not independent but are coalescing, even matted branches. These branches are (1) the physics of the sea, (2) the chemistry of the sea, (3) marine biology, and (4) geologic oceanography. How these different aspects of oceanography are interwoven so as to form a network will now be indicated and the close interrelation will be made clearer in subsequent parts of this statement.[18]

The ocean is a complex system which is well beyond the reach of researchers of just one scientific field. Therefore it was necessary that scientists from several different fields study the marine natural phenomena with the knowledge and methodologies of their main fields. In Vaughan's framework, physical, chemical, and geological oceanography and marine biology were to be the four branches, each having its domain distinct from the others but at the same time closely interconnected. Researches in the four branches would eventually form a "network."

Vaughan's definition of oceanography and his distinction of the sub-branches were radically new to the Scripps Institution, the organization of which was still based on the Ritterian concepts. The institution was basically a marine biological station where study of marine organisms occupied the central position and physical study of the sea was secondary. As a biologist, Ritter could not but think of marine biology as the core part of oceanic science. Even though Ritter wanted to enlarge the physical oceanography program at the Scripps Institution by changing its name, it was only to raise it to an equal status with marine biology and not to exceed it. And Ritter hardly ever mentioned chemical and geological oceanography separately. He probably used the term physical oceanography, or hydrography, comprehensively to include chemical and geological

[18] Ibid.

study. He gave little, if any, attention to the geology of the ocean floor and the chemistry of seawater during his entire directorship. Ritter pursued the interconnection of biology and oceanography, or of biological and physical oceanography, and in his mind, unlike Vaughan's, there were only two branches of oceanography, not four. But to the new director, chemistry and geology had equal weight with physics or biology, which made it impossible for marine biology to dominate the other fields. Therefore, the most conspicuous outcome of the new director's ideas was lowering of marine biology's status within the institution's research program. Biology, which constituted more than half of the Scripps Institution's scientific program now came to occupy only one fourth!

It should not go unnoticed, however, that Vaughan's idea was not in total disagreement with that of Ritter. Although Vaughan's understanding of oceanography had a very different outer appearance from Ritter's, it still possessed some fundamental features of his organismal philosophy. Ritter emphasized that the goal of science—biological science, in particular—had to be the understanding of the organism as a whole.[19] Scientists should study parts of an organism, but they nonetheless have to pay more attention to the interconnectedness of the parts and their relationship to the whole. In a similar vein, Vaughan's research program of oceanography emphasized that the different aspects of the oceanic phenomena were all connected. In the above passage, he wrote that the four "different aspects of oceanography are interwoven" and that there exists "the close interrelation" among them.[20] Although Vaughan clearly distinguished the four branch fields of oceanography, he did not see the distinction as natural or immutable. Instead, he recognized the four oceanographic branches only "for convenience." The different aspects "form a network" and this interconnected and closely "interrelated" network is the ultimate goal of oceanography. While assuming the need for the branches for practical reasons, he never lost sight of the ocean as a whole. Overall, Vaughan's attitudes and his way of thinking conformed well with Ritter's "organismal conception of life." It was in a sense an organismal conception applied to the ocean as a whole. In this respect, Vaughan certainly shared his predecessor's holistic and organismal philosophy, which must have made Ritter satisfied.

How did Vaughan come to have such ideas (mainly the division of the four

[19] Ritter, *Unity of the Organism*.
[20] Vaughan, "Scripps Institution."

branches), then? The first thing that we can turn to is his broad educational background. He himself had studied a considerable amount of physics, chemistry, biology, and geology. As mentioned above, Vaughan studied in the Physical Sciences program and majored in physics at the Tulane University, where he also studied some biology and geology.[21] He even taught physics and chemistry at a junior college for three years. At Harvard, he took a substantial number of biology courses as well as many geology and paleontology courses. Moreover, as a paleontologist whose main expertise was in the field of coral reef studies, he was familiar particularly with biological and geological oceanography and felt the need for some knowledge of physical and chemical features of the sea. As a result, Vaughan came to know something about all the four natural science fields relevant to oceanography and, from the years of his own experience at sea, had a firm belief that all of them were necessary in understanding the ocean.

We can also think about the influence of the British oceanographic tradition on Vaughan's thinking. Sir John Murray, who certainly played a great role in shaping Vaughan's oceanographic ideas, was a core member of the famous *Challenger* Expedition's scientific staff. He had been on board H.M.S. *Challenger* from the beginning of its voyage in 1872 until its end in 1876, and later became the director of the Challenger Office.[22] Moreover, after director Wyville Thomson's death in 1882, Murray became responsible for the *Challenger* Report. The monumental expedition aimed to investigate "all aspects of the deep sea" and the *Challenger* Report included "all that was known on their subjects at the time."[23] It means that the Challenger scientists tried all the possible approaches in their scientific work at sea. All of Vaughan's four fields were scrutinized in the report. Although, as Susan Schlee noted, the expedition's contributions to physical and chemical oceanography were relatively meager when compared with its accomplishment in the other two fields, Murray must have realized the importance of physical side of the ocean later. He participated as a British delegate in the early phase of the international cooperative investigation of the North Sea, which would later develop into the International Council for the Exploration of the Sea (ICES), and must have known about the great achievements the Scandinavian scientists had made in the field of

[21] Thompson, "Thomas Wayland Vaughan," 400-401.
[22] Susan Schlee, *The Edge of an Unfamiliar World: A History of Oceanography* (New York: E.P. Dutton, 1973), 107-138.
[23] Ibid., 107, 126.

physical oceanography since late nineteenth century. It is, therefore, natural that Vaughan inherited that aspect of the British oceanographic tradition best exemplified by the Challenger, and it must have played some role in the forming of his own idea of oceanographic research characterized by the four branches.

There was yet another reason for Vaughan to take this model favorably. Running the Scripps Institution according to Ritter's idea of oceanography would inevitably mean that there would be only a small, if any, room for his own field, geological oceanography. Ritter emphasized marine biology and physical oceanography, but he rarely mentioned the need for marine geology. Revealing of Ritter's neglect of marine geology was the fact that never in the past had any geologist been engaged in Scripps' research project. In order to secure a proper space for this invaluable part of oceanography, and also for chemistry, Vaughan had to replace Ritter's narrow program with his broader one. Only the idea that every aspect of the sea, i.e. physical, biological, chemical, and biological, should be studied in oceanography would ensure the execution of more balanced and comprehensive oceanographic research. In this respect, it was inevitable that Vaughan would lay out the four-branch plan for the Scripps Institution's program of oceanographic research as well as its organization.

4. The Department of Oceanography of the University of California

At a conference on physical oceanography held in November 1925, Vaughan stated that "under the directorship of Doctor Ritter important researches in oceanography other than those of purely biological significance had already been initiated."[24] Yet, "certain administrative and scientific adjustments" had to be made at the institution "because of the change in its scope and policy." During almost two years since he took

[24] Vaughan, "The Oceanographic Investigation of the Scripps Institution of Oceanography, with Special Reference to Marine Hydrography," *Bulletin of the Scripps Institution of Oceanography*, 12 (1926): 3-13. It was presented at the Conference on the Physical Oceanography and Marine Meteorology of the Northeast Pacific and the Climate of the Western Part of the United States on November 6 and 7, 1925.

office as director of the Scripps Institution in February, 1924, Vaughan had made some revolutionary "adjustments," the kernel of which was to enhance the oceanographic fields "other than those of purely biological significance."

In order to rebuild the Scripps Institution, the first thing Vaughan set out to do was to reconstitute its scientific staff according to his blueprint. Vaughan's new policy required active research in all the four branches of oceanography, which would be possible only when the institution possessed enough able workers in each branch. Yet the reality was far from that as there were, at that time at Scripps, several biologists and only one physical oceanographer, George F. McEwen. There was no chemical oceanographer or geological oceanographer, except for Vaughan himself, on the Scripps staff. The first official decision director Vaughan had to make, therefore, was to find a chemical oceanographer who would be able to build a chemical oceanography program that would be strong in itself and, at the same time, operate in harmony with the work of pre-existing branches. His choice was Erik G. Moberg, who had been working mostly with McEwen at Scripps during Ritter's last years as a graduate assistant. Moberg was then a Ph.D candidate in the Department of Biochemistry at Berkeley and he received his degree in the next year.[25] He was one of the first American chemical oceanographers, and his role at the institution during Vaughan's years would be tremendous both in his own field and as an expert in working at sea.

By successfully hiring a suitable chemical oceanographer for the institution, Vaughan managed to take the first step toward his goal of making Scripps oceanographic. Moberg's joining the Scripps staff meant that his picture of the four research branches was beginning to materialize. Now the institution came to have at least one staff member in all the four oceanographic branches, with physical oceanographer McEwen, chemical oceanographer Moberg, biological oceanographer Winfred E. Allen, and geological oceanographer Vaughan. Scripps also had Percy S. Barnhart, curator of aquarium and collector, and as non-resident staff member marine zoologist Calvin O. Easterly of Occidental College (who died in 1928).

Vaughan's job with the staff included not only adding new members but also eliminating those who did not fit in his scheme. Wesley Clarence Crandall had been with

[25] Raitt and Moulton, *Scripps Institution*, 85-86, 100.

the institution since the summer of 1911 when he had conducted the study of kelp.[26] He was instructor of biology at the San Diego State Normal School before joining the Scripps staff in February, 1913 as business manager. For over a decade, he had been the most devoted worker of the institution in charge of business matters, master of the institution's ship *Alexander Agassiz*, manager of the institution's laboratory buildings, cottages, and grounds, and at times even took care of Ritter's garden and Sumner's mice. He also participated in the war effort during the World War as a kelp expert, and in subsequent years was a member of the "Committee on Conservation of Marine Life of the Pacific" of the National Research Council. Despite the tremendous work Crandall had been doing for the institution, however, Vaughan thought he could manage both scientific and business matters of the institution himself and that the office of business manager was unnecessary. Crandall resigned at the end of April and became a business agent for Ellen B. Scripps.[27]

The problem with biologist Francis B. Sumner was more complicated. He was a prominent scientist widely known at the national level. He was at that time the only full professor of the university among the Scripps staff members with the exception of director Vaughan. He was a member of the National Academy of Sciences. He even served as Acting Director during the period of six months when the directorship was vacant because of Ritter and Vaughan's travel to the Pacific Science Congress in Australia.[28] Yet his research did not fit well into Vaughan's new oceanography program, since it was purely biological and in no sense was related to the ocean. Sumner's project was a breeding experiment of field mice *Peromyscus*, with which he wanted to solve important problems of genetics and evolution.[29] It was a long-term and very expensive project and Sumner had been spending a considerable amount of money on it. Since E. W. Scripps, who had always been interested in population problems and social aspects of biology, was very much interested in this study, he created a special fund for Sumner's work. In the 1910's, when Ritter did not want to confine the institution's scope only to

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[26] Ibid., 61-100.
[27] Ibid.
[28] Ibid.; William B. Provine, "Francis B. Sumner and the Evolutionary Synthesis," *Studies in History of Biology*, 3 (1979): 211-240.
[29] For a general overview of Sumner's work on *Peromyscus*, see Francis B. Sumner, "Modern Conceptions of Heredity and Genetic Studies at the Scripps Institution," *Bulletin of the Scripps Institution for Biological Research*, 3 (1917): 2-24.

marine biology, Sumner's work was highly valued and it could become one of the mainstream researches at Scripps.

Sumner must have been the person at the Scripps Institution most concerned about the new direction Ritter and others had chosen for its future. He was well aware that his research was quite apart from the rest of the projects going on in Scripps, and he knew that his project did not match well with the institution's new direction. Thus, he could certainly foresee the difficulties that he was soon to face after Ritter's retirement. During his term as Acting Director, Sumner once remarked,

> There is doubtless need enough for an oceanographic institution, of perhaps international scope, and it may well be that the Scripps Institution has been wisely chosen as the nucleus of such an organization. But it may be permissible to say, in conclusion, that if such a course is adopted there will be left a great gap to be filled. We shall then need a new institution which shall be in the words of our Regents, "an instrument for the most liberal biological research," one in which the problems of biology are kept in the foreground, and where the material for study may be chosen without reference to whether it chances to be marine or terrestrial in its habitat.[30]

Sumner was certainly right in expecting a difficult time as there would be no room for his study of terrestrial animals at the renewed Scripps Institution. Vaughan made it clear that he did not want this far-from-oceanographic work to be done in his institution. Vaughan, who was not a total outsider of biology, was not ignorant of the importance of Sumner's work, however, and wanted it to be continued somewhere else. So Vaughan tried to move Sumner's chair to the Zoology Department at Berkeley and to transfer his fund to the general budget of the Scripps Institution. To Vaughan's dismay, Sumner's transfer to Berkeley did not happen and Sumner could remain in La Jolla. Sumner, however, could not continue the *Peromyscus* study at the oceanographic institution if he were to remain as a member of that scientific community. Belonging to the Scripps staff,

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30 Francis B. Sumner, undated speech preserved in SIO Archives. Cited from Raitt and Moulton, *Scripps Institution*, 99.

he now had to contribute to the institution's oceanographic program, and decided to begin a new line of research—physiological study of fish. It was rather a returning to his old work as his main field had been marine biology before coming to the Scripps Institution in 1913 for the *Peromyscus* study.[31]

As the Scripps Institution was now being transformed from biological to oceanographic, its place within the University of California had to be changed as well. One thing that Vaughan noticed as he assumed the director's office was that Scripps had not maintained close relations with the several departments of the University of California whose scientific interests overlapped with those of the institution. He believed that the relationship had to be restored, or newly formed, and that it was a crucial job in placing the institution properly within the whole university system. Vaughan wrote to President William Wallace Campbell on March 11, 1924:

> Besides the matters above indicated to which I think we should give consideration, the relations of the Institution to the neighborhood in which it is situated and to the University faculty need to be given attention. It is my belief that steps need to be taken to make the contacts between the Institution and the people in San Diego and La Jolla closer and there should be cordial cooperation between a number of the University Departments in Berkeley and the Institution. For some reason, which I do not understand, the Institution seems to have lost contacts both with the local and University people. It may require some time and tactful handling of these matters in order to bring about the desired relations.[32]

Vaughan expressed similar concerns to other people such as Charles Kofoid, zoology professor and the former Assistant Director of Scripps, and Walter Moris Hart, Dean of the University. To Hart, Vaughan wrote:

> There should be close cooperation between at least four or more of the

[31] Provine, "Francis Sumner," 211-214; Sumner, "Discontinuance of the La Jolla Peromyscus Program," *Science*, Vol. 72, No. 1871 (Nov. 7, 1930): 477-478.
[32] Letter from Vaughan to W. W. Campbell (March 11, 1924), SIO Records of Director.

> different departments. There are the Departments of Zoology, Botany, Geology, and Biochemistry. In some of the oceanic problems we should have the assistance of the Departments of Physics and Chemistry. I also wish to take up with the Department of agriculture some of the problems of soil physics which are not greatly different from the physics of marine sediments.[33]

He particularly mentioned in his letter to Kofoid William A. Setchell and Nathaniel L. Gardner of the Botany Department, who had been conducting studies of marine plants for many years. Vaughan was interested in "the work by [Professor Setchell] and Professor Gardener on Marine Algae" and asked them to "utilize such facilities as the Scripps Institution has to offer."[34] Setchell and Gardener had been working on microscopic marine plants for some years yet, strangely enough, their work had not been done in any relation to the Scripps Institution.[35] Tying their work to Scripps seemed necessary to Vaughan as he intended to make his institution a center of all oceanographic work done in the University of California.

Vaughan might have had more in mind when he proposed the idea of drawing those Berkeley departments into the affairs at La Jolla. Scripps had had a special relationship with the zoology department, and when Vaughan sought to rebuild it as an independent scientific and administrative unit of the University of California it certainly was a burden. Having been founded by the members of the zoology department, the Scripps Institution and its predecessor, the Marine Biological Association of San Diego, had been subsidiary to the zoology department in some ways. It had long been a summer laboratory of zoology professors and researchers, providing them with valuable chances to work on marine life as well as cottages to stay in. The first step to overcome the older, unequal interrelationship was to remove the zoology department from its long-held position as the institution's main sponsor and to make it just one of several related departments at Berkeley. The new relationship of "close cooperation" with those several

[33] Letter from Vaughan to Walter M. Hart (March 12, 1924), SIO Records of Director.
[34] Letter from Vaughan to Charles A. Kofoid (March 6, 1924), SIO Records of Director.
[35] Peter Neushul and Zuoyue Wang, "Between the Devil and the Deep Sea: C. K. Tseng, Mariculture, and the Politics of Science in Modern China," *Isis*, 91 (2000): 59-88. See pp. 64-66 for Setchell and Gardner.

departments, including the zoology department, would certainly contribute to the ultimate emancipation of Scripps from its old patron, and of oceanography from biology.

It was a necessary step for Vaughan's plan for the Scripps Institution of Oceanography to acquire its proper place within the university. Vaughan's new science, oceanography, had to be an independent science that deserved a place which other, already established scientific fields had long been enjoying—the status of a university department. Vaughan continually called his institution "department of oceanography of the University of California," which had to be located in La Jolla, and not Berkeley, because of the peculiarity of the science.[36] Vaughan's idea of making Scripps a virtual "department of oceanography" was a natural outcome of his concept of oceanography, which demanded that oceanography should be a science of the sea and not merely of marine organisms. Having close relationship with the seven departments in Berkeley, including zoology, would fit very well with Vaughan's idea that oceanography was a field consisted on its branch fields. In this respect, the Scripps Institution's special relationship with the zoology department was, for Vaughan, far from desirable, and he had to struggle for some time to break that tie.

The official name change did not automatically grant Scripps the independence from the zoology department, although there was no formal tie between them. Members of the zoology faculty, especially Charles Kofoid, who had contributed significantly to the founding and management of the institution, still considered it to be a close kin to their department. The disparity between Berkeley and La Jolla was first exposed in November, 1925, when Vaughan expressed his strong objection to the composition of a Scripps graduate student's dissertation committee.[37] Vaughan was informed of the decision on George F. Sleggs' graduate council, which was constituted of six professors of the University of California—Kofoid, Samuel J. Holmes, George D. Louderback, Joseph Grinnell, Jacques Loeb, and Vaughan. These committee members were from the departments of zoology (Kofoid, Holmes, and Grinnell), geology (Louderback), physiology (Loeb), and the Scripps Institution of Oceanography (Vaughan). When Vaughan was informed of the decision he was enraged at the distribution of departments to which each professor belonged. Vaughan immediately responded by writing to the

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[36] For instance, see Vaughan, "Scripps Institution," 14-15.
[37] Letter from C. B. Lipman to C. A. Kofoid (November 27, 1925), SIO Records of Director.

Dean of the Graduate Division that, "[t]o say that I am astonished by the copy of your letter dated November 27 to Professor Kofoid is a mild expression of my feelings."[38] He noted three things that he thought unreasonable. First, the committee was overloaded with zoologists (three out of six); if three zoologists were to be included, then three members of the Scripps Institution had to be there, too. Second, it was problematic if Kofoid was to become the chair as the decision indicated. The chairman had to come from neither the zoology department nor the Scripps Institution. Finally, among the listed professors, only geologist Louderback was familiar with the Institution's development since Vaughan's arrival and, thus, Vaughan wanted to see someone like biochemist C. L. A. Schmidt, microbiologist K. F. Meyer, or botanists Gardner and Setchell instead of the ones in the list. Vaughan thought that an immediate action was needed and he proposed a meeting in Berkeley with some influential members of the university including two colleagues, two deans, and the University's vice president.[39]

This episode shows well how sensitive Vaughan was to the excessive influence from the zoology department and the attitudes of the university administration which took it for granted the intimate relationship between the two. On the other hand, it tells us of another aspect of Vaughan's strategy as a newly appointed Scripps director who came from outside the university. It is interesting to see the difference between the two groups of Berkeley professors that Vaughan preferred and disliked. Besides the fact that the proposed committee consisted of too many zoologists, the members obviously differed from those not included in terms of their former relationships with the Scripps Institution. Kofoid and Holmes were early members of Ritter's marine biological activities. Grinnell, director of Berkeley's Museum of Vertebrate Zoology as well as zoology faculty member, shared much of Ritter's scientific ideals and had long been his close colleague. Loeb, who did not participate in the work of Scripps directly, nevertheless was renowned for his work in marine biology done at Woods Hole's Marine Biological Laboratory. Therefore, considering that Sleggs' major field was marine biology, or biological oceanography as Vaughan would have preferred, the constitution of his committee was, in a sense, quite reasonable. It also did not neglect the idea that knowledge of marine environment was indispensable for the study of marine organisms

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[38] Letter from Vaughan to C.B. Lipman (December 2, 1925), SIO Records of Director.

[39] Letter from Vaughan to G.. D. Louderback (December 3, 1925), SIO Records of Director.

since two geologists were included—Louderback and Vaughan. It was perhaps the best combination of experienced experts to advise on Sleggs' graduate research in marine biology, considering the practical difficulty of gathering at one place the people from Berkeley and La Jolla.

The other group, on the other hand, was constituted of those people who did not have previous ties to the Scripps Institution until Vaughan's arrival at the University of California. In order to transform Scripps from a biological to an oceanographic institution, it was necessary for Vaughan to make connections with those people whose academic expertise was related to the ocean but not directly in marine biology. In other words, they were Vaughan's chosen men who would replace the older patrons of Scripps in Berkeley, the majority of whom were at the zoology department. They would block unnecessary interference from the zoology department, support Vaughan's oceanographic program, and assure its success. In this respect, Vaughan had reasons to be discontent with the proposed committee, and it was more a power struggle than a purely academic concern for his student. It was a good occasion for the new director Vaughan to display his power over the academic and administrative matters of his student and, hence, his institution's independence from the zoology department.

In order to make the Scripps Institution a department of oceanography, there was more to be done than to confirm its institutional independence within the university structure. There were certain things an academic department had to have. Until then, Scripps was heavily research-oriented, and its educational function was almost negligible. Ritter emphasized learning through research, and graduate students interested in marine science worked as assistants to the Scripps staff members. Scripps was basically a research institution and it offered no formal courses. Moreover, Ritter was never interested in the education of undergraduate students who might later come to his institution and did not give them any guidelines for study. The student researchers and assistants working at Scripps, therefore, usually did not have background in oceanography nor comprehensive knowledge of scientific fields other than their major field. In most cases, they had completed the scientific coursework in their home department in Berkeley before coming down to La Jolla where they would be engaged in more specific research. No degree was conferred through Scripps, and the students would receive their graduate degrees from their home departments.[40]

Things had to be different at the new Scripps, which was to be the department of oceanography. Students needed to enroll in Scripps' academic program and earn their degrees in oceanography. Academic curriculum had to be arranged and courses in various aspects of oceanography had to be opened there, although it was necessary at times to send the students to Berkeley to attend certain courses. Vaughan did it. Graduate courses in the four oceanography branches were opened and taught by the Scripps faculty members according to their specialties. The first doctoral degree in oceanography (biological) was conferred in 1930 to Ancel Benjamin Keys.[41] Vaughan also set the undergraduate requirement for future applicants to the Scripps' graduate program. There, his ideal for the emerging field of oceanography and its students was well reflected. As a prerequisite for graduate study at Scripps, students were expected to have studied "4 years in physics, 2 years in chemistry, 4 years in mathematics and mechanics, 1-1/2 years in botany, 1-1/2 years in zoology, 1 year in paleontology, the equivalent of 2 years in geology and 1/2 years in mineralogy" according to Vaughan's initial scheme.[42] The students who fulfilled this requirement would be perfectly prepared for advanced study in all aspects of oceanography, not just one. They would be more likely to become proper oceanographers in the future, and not narrow-sighted marine biologists or hydrographers, who could not grasp the big picture. This requirement was "governed somewhat by my own undergraduate college experience," Vaughan confessed.[43] Indeed, he was an unusual oceanographer at that time, who could understand the work going on in all the four oceanographic fields, and he attributed this to his former education. The final version of the undergraduate requirement turned out to have general and special requirements. The general requirement included five courses in mathematics, two courses in chemistry, four courses in physics, one course in paleontology or in a biological science, totaling thirty four credits, as well as reading knowledge of scientific German or French. The special requirement was a major in one or a combination major in two of biochemistry, botany, chemistry, geology, paleontology, physics, plant or

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[40] For instance, Scripps affiliates Henry Homer Collins (1919) and Ralph Ruskin Huestis (1924) received Ph.D degrees from the zoology department and Erik Moberg (1925) from the department of biochemistry. Raitt and Moulton, *Scripps Institution*, 192.

[41] Ibid.

[42] Letter from Vaughan to Lipman (December 1, 1924), SIO Records of Director.

[43] Ibid.

animal physiology, or zoology.[44]

While struggling within the boundary of the University of California to create the first American oceanography department at Scripps, Vaughan also tried at the national level to make oceanography an established scientific discipline. He felt that oceanography lacked something important that any established scientific field had to have. At that time, there was no such thing as an oceanographic journal in the United States, and Vaughan was deliberating on the possibility of publishing one at the University of California under the control of the Scripps Institution. Henry Bigelow, in his response to Vaughan's tentative proposal, described clearly that situation and asserted the need for a journal on February 25, 1924:

> The plan of starting a series of oceanographic publications at the University of California is an excellent one. There is no medium in this country when the very various subjects proper to oceanography can all be brought together: nor in Europe, either, unless the "Int. Revue Hydrogr. & Hydrobiol." is brought to life again. . . . It would be also vastly helpful if you could run a brief reviewing section.[45]

In January of 1925, Vaughan went further with that idea. The Scripps Institution had been publishing the *Bulletin of the Scripps Institution for Biological Research* since 1916, where authors wrote mostly plain and comprehensive articles for the purpose of propagating the work done at Scripps. Therefore it was not a professional journal in which oceanographers at Scripps and elsewhere could publish their most recent scientific findings. In the past, *The University of California Publication in Zoology* had served the function that Vaughan was considering. It had certainly been a good place for the Scripps scientists to publish their work when the institution consisted mostly of biologists. Ritter and Kofoid were its longtime editors and this series often contained "Contributions from the Laboratory of the Marine Biological Association of San Diego" and, later, "Contributions from the Scripps Institution for Biological Research." But for the new Scripps Institution, the *Publication in Zoology* was far from satisfactory,

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[44] This requirement appeared in Berkeley's *General Catalogue*. See, for instance, *General Catalogue* (Berkeley: University of California, 1934-35), 320-321.
[45] Letter from Henry B. Bigelow to Vaughan (February 25, 1924), SIO Records of Director.

although it was still useful to some degree for the Scripps marine biologists. Those whose main field was physical or chemical oceanography, such as McEwen and Moberg, published in the Publication in Zoology only the articles that had direct implications for marine biology.

Vaughan wanted to found an oceanographic journal that would not only replace the *Publication in Zoology* for Scripps members but that could become a national journal for all American ocean scientists, thus bringing together all the oceanographic work done in the country. It would be catalytic to the unifying of the scattered work related to the ocean under the umbrella of oceanography. In order, first, to persuade the president of the university W. W. Campbell of the urgent need for the new *University of California Publication in Oceanography*, Vaughan tried to get opinions of experts. He sent letters to a dozen prominent American scientists who had done significant work related to oceanography. [46] As Bigelow described the current situation of American oceanographers, they strongly sympathized with Vaughan and encouraged his plan. There was one exception, however, whose basis for the objection was that American marine scientists already had to read so many scientific journals, such as the ones in geophysics, geology, physics, chemistry and biology, and that publishing another such journal would only add more burden to their reading list. Now with the generally favorable support from leading American ocean scientists, Vaughan proceeded to the university administration with his publication series project. The ambitious plan was not realized in the form he had initially envisioned, but in a different shape. Rather than *U.C. Publication Series in Oceanography*, it was decided that the existing *Bulletin of the Scripps Institution of Oceanography* would split into “Non-Technical” and “Technical” series. The Latter played the role that Vaughan’s proposed new journal was expected do for oceanographers.[47]

[46] Letter from Vaughan to G.W. Littlehales (January 26, 1925), SIO Records of Director, was one of them.

[47] The technical series of the *Bulletin of the Scripps Institution* began to appear in 1927.

5. Forming a Network: Oceanography as a Cooperative Enterprise

'Cooperation' may be the word that best describes Vaughan's directorship at the Scripps Institution of Oceanography. Oceanography itself was essentially a cooperative venture, the four branch fields of which had to be "interwoven" in order to produce the full picture of the ocean. The study of only one aspect of the sea is imperfect unless its relationship with the rest was properly indicated. The life of marine animals could be fully understood only if the physical, chemical, geological, and biological conditions of its environment were known, for example. To achieve this end, oceanographers had to work together, assisting one another. Vaughan also emphasized the cooperation with the scientists of related fields, and at Scripps he did this by making major Berkeley professors of biochemistry, botany, geology, and agriculture the supporters of his oceanographic program. They frequently talked with Vaughan, advised on the institution's affairs, and often educated Scripps' graduate students in their own fields.

Vaughan's insistence on cooperation went beyond the boundary of the Scripps Institution of Oceanography, and the University of California, too. His previous career in Washington D.C.'s scientific circle gave him major impetus for that direction. Having started working at the U.S. Geological Survey while he was still a graduate student at Harvard, Vaughan spent about thirty years there, frequently associated with other federal agencies such as the Smithsonian Institution, U.S. Coast and Geodetic Survey, the Navy's Hydrographic Office, and the Carnegie Institution of Washington.[48] Vaughan's personal relationship with the major figures of these institutions helped him to form the cooperative connection between Scripps and those institutions. They usually knew what Vaughan had been doing and what he was trying to do with oceanography and understood the need for institutional cooperation in the study of this science.

Even before leaving Washington for California, Vaughan succeeded in forming the first such connection with the U.S. Coast and Geodetic Survey. He wrote to President Campbell that "[b]efore I left Washington, I arranged with Colonel Jones, the Director of the Coast & Geodetic Survey, for certain cooperation between the U.S. Coast &

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[48] Elizabeth N. Shor, "The Role of T. Wayland Vaughan in American Oceanography," in M. Sears and D. Merriman, eds., *Oceanography: The Past* (New York: Springer-Verlag, 1980), 127-137. See also Thompson, "Thomas Wayland Vaughan."

Geodetic Survey and the Scripps Institution."[49] The relationship was reciprocal, beneficial to both institutions. The Coast and Geodetic Survey was, at that time, engaged in echo sounder research and was planning for an expedition with its survey vessel *Guide* which had the Sonic Depth Finder installed on it.[50] The steamer *Guide* was to travel from New London, Connecticut, through the Panama Canal, to San Diego getting continuous contour of the sea floor. Vaughan made the agreement with the Coast and Geodetic Survey that "the bottom samples and the water samples collected on its voyage" as well as "a copy of the temperature and depth records" were to be given to the Scripps Institution.[51] The Survey also agreed to make "special observations and collections" during their cruises upon the requests of Scripps researchers. On the other hand, Vaughan promised "to let the Coast & Geodetic Survey have copies of the salinity determinations of the different water samples collected as promptly as possible." With this deal, the Scripps Institution could get valuable data and samples of sea water and planktons, without having the trouble of making its own expedition. The Survey was able to get the salinity results quickly with the help of the Scripps staff. According to Vaughan, "[t]he Salinity determinations have been of much assistance to the Coast & Geodetic Survey in the determination of the rate of propagation of sound waves through the water and in the standardizing of the sonic method of the determination of depth." On the other hand, the sonic method of determining position at sea needed seaside stations, and one such station was established at Scripps. Vaughan also agreed on installing a tide gauge at the institution.

Similar cooperative relationships were soon formed with other institutions as well. Vaughan wrote to President Campbell on March 11,

> You know that there is now cordial and I think fruitful cooperation between the Institution and the U.S. Coast and Geodetic Survey. We also have pleasant and helpful relations with the U.S. Bureau of Light Houses, the U.S. Bureau of Fisheries, the Geological Survey, and the

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[49] Letter from Vaughan to W. W. Campbell (February 21, 1924), SIO Records of Director.

[50] Schlee, *The Edge of an Unfamiliar World*, 250-252. The Sonic Depth Finder was developed by Harvey Cornelius Hayes in 1922. Hayes was working for the U.S. Naval Experiment Station in New London.

[51] Letter from Vaughan to W. W. Campbell (February 21, 1924), SIO Records of Director.

> National Museum. I am retaining official connection with both the Geological Survey and the National Museum. I hope that we may also bring about similar relations with the Navy and several of the Bureaus of the Department of Agriculture, including the Weather Bureau. The relations with the Carnegie Institution are most cordial and I hope that I may see Dr. Merriam when he comes west next week.[52]

Cooperative work with such diverse institutions dominated the work of the Scripps Institution during most of Vaughan's directorship. Vaughan could keep his staff busy with analyzing the vast amount of samples and data passed on by their outside colleagues.

In addition to forming the network of cooperative oceanographic work with government and private institutions, Vaughan had a bigger picture of national cooperation in the country that bordered on two great oceans. Scripps had been studying the Pacific Ocean since it had become the first American oceanographic institution in 1925 with its name change. On the Atlantic Coast, however, there was no such institution that was devoted purely to the study of the ocean without practical purposes, such as fisheries and navigation. In the 1920's, there emerged people who had the vision of founding an oceanographic institution on the East Coast. Frank R. Lillie, professor of zoology at the University of Chicago and director of the Marine Biological Laboratory at Woods Hole, initiated the establishment of the committee on oceanography of the National Academy of Sciences in 1927.[53] The Rockefeller Foundation was interested in oceanography at that time, and the committee had a good prospect of getting financial support for several private oceanographic institutions, including the newly proposed ones.

Vaughan's participation in the committee brought some financial gains for the Scripps Institution. He was trying to build a new laboratory building mainly for physical and chemical oceanography. In April, 1930, the Rockefeller Foundation provided 40,000

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[52] Letter from Vaughan to W. W. Campbell (March 11, 1924), SIO Records of Director.

[53] Raitt and Moulton, *Scripps Institution*, 108-111; Henry B. Bigelow, "Report on the Scope, Problems, and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies," Report of the Committee on Oceanography of the National Academy of Sciences, 1929.

dollars for the building of the laboratory while the rest of the total amount came from the State of California and Miss Scripps ($40,000 each). It was a disappointment for Vaughan, however, since he expected more for his institution. Vaughan's expectation was reasonable because the total amount of Rockefeller funds given to American oceanographic institutions turned out to be tremendous. The Rockefeller foundation provided $50,000 for the Bermuda Biological Station for Research, and $265,000 for the University of Washington's proposed Puget Sound oceanographic institution. For the Woods Hole Oceanographic Institute, $3 million was given for the institution's establishment, let alone the large amount that went to Woods Hole in the following years. The relatively small share for Scripps resulted partly from the committee members' general feeling that it was already doing well with the support from the state university and its private patrons such as the Scripps family.[54]

Vaughan's intention with the committee was not confined to potential financial benefits for his institution, however. He truly wanted to see oceanography flourish in the United States, and believed that it could only be achieved by establishment of oceanographic institutions like Scripps on both coasts of the country and forming the cooperative network among them. Vaughan did his best for the committee, and being the director of the only oceanographic institution in the country, was, in fact, the best person to talk about the contemporary state of American oceanography and its future. And he was deeply interested in the plan for the new East Coast institution for oceanographic research. According to Raitt and Moulton, "Vaughan functioned as chief consultant in planning the Woods Hole facilities, allocation of finances and program, and was appointed to the original board of trustees." It was reasonable for him to be willing to help the founding of a new institution, which might become a strong competitor of Scripps. Considering the size of the Scripps' scientific staff and its financial capacity, Vaughan's institution could manage to cover only a small part of the Pacific Ocean. Moreover, Scripps could hardly dare to participate in the study of the Atlantic Ocean. In that aspect, there was no reason for Vaughan to feel uncomfortable with the plan for a sister institution at Woods Hole. Rather, it would be beneficial not only for Scripps but for oceanography itself and the whole country. He was, on the other hand, quite confident of his institution's superiority. Vaughan wrote to the U.C. President that "it

[54] Raitt and Moulton, *Scripps Institution*, 108-111.

would be ten years or even more before the institution on the Atlantic could catch up to where the Scripps Institution now is."[55]

Vaughan's cooperative ideal for the progress of oceanography was not confined within his mother country. Since the ocean is a complex system that could not be understood well by studying only a small portion of it adjacent to each nation, cooperation among different countries that had the scientific ability for intensive oceanographic work was necessary. It was an idea already well proved by the work of the International Council for the Exploration of the Sea (ICES) in its study of the eastern part of the Atlantic Ocean. What Vaughan wanted to do as the director of Scripps was to form such an international cooperative network for the study of the Pacific Ocean. His participation in the international oceanographic meetings began in 1920, years before becoming director at Scripps.[56] At the Pacific Science Congresses, Vaughan tried to enhance the cooperation among the member countries. After the second Congress held in Australia, he wrote to McEwen,

> While in Australia I succeeded in having first the Section of Geography and Oceanography and then the general Congress pass a resolution looking toward a cooperative study of the surface temperatures, salinities, hydrogen ion concentration, and currents of the Pacific, particularly of the northern Pacific. . . . I did this largely for the purpose of bringing out and strengthening the investigations you have been making in physical oceanography and the relation of oceanic conditions to continental meteorology.[57]

At the third Congress in Japan, in 1926, the International Committee on the Oceanography of the Pacific was established and Vaughan served as its chairman for ten years. This committee was instrumental in encouraging oceanographic work in the Pacific Ocean and with it Vaughan and others coordinated the work by each group of

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[55] Letter from Vaughan to W.W. Campbell (November 16, 1929), cited from Shor, "Role of T. Wayland Vaughan," 133.
[56] Shor, "Role of T. Wayland Vaughan."
[57] Letter from Vaughan to George F. McEwen (October 19, 1923), cited from Shor, "Role of Wayland Vaughan," 134.

researchers from many countries, among them Australia, Japan, the Philippines, and the United States. Vaughan participated in the first six meetings of the Pacific Science Congress.

As Vaughan had contributed to international cooperation for many years, there was a general consensus among leading scientists that he was the expert on the international aspects of oceanography. In 1931, the Committee on Oceanography of the National Academy of Sciences was engaged in a project to investigate the international aspects of oceanographic research. Lillie, among others, thought that Vaughan was the right person for this job, and the Committee commissioned him to prepare the report.[58] It was a time-consuming job as it required Vaughan to travel around the world to visit centers of oceanographic work and collect information from them. He left the Scripps Institution for the project in August, 1932, and returned after fourteen months. The report, *International Aspects of Oceanography*, which was published in 1937 by the National Academy of Sciences, contained content written by Vaughan and others.[59]

Cooperation is the keyword in understanding Vaughan's oceanography and the Scripps Institution under his directorship. The ocean is vast both in its physical magnitude and the complexity of its system, which makes it inevitable for its human investigators to collaborate. Vaughan was well aware of that characteristic of oceanography, and thought it necessary to form an inter-institutional cooperation network around the Scripps Institution in order for his limited number of workers to carry out the grand task of disclosing the secrets of the Pacific Ocean. The close and reciprocal relationship between Scripps and other federal and private institutions proved not only a blessing, however. It was both strength and weakness of Vaughan as the director of an oceanographic institution.

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[58] Raitt and Moulton, *Scripps Institution*, 117-118; Shor, "Role of T. Wayland Vaughan," 134.
[59] T. Wayland Vaughan, et. al., ed., *International Aspects of Oceanography: Oceanographic Data and Provisions for Oceanographic Research* (Washington, D.C.: National Academy of Sciences, 1937).

6. Problems and Limitations of Vaughan's Directorship at Scripps

In November, 1929, the Carnegie Institution's nonmagnetic research vessel, the *Carnegie*, which had been designed specifically for geomagnetism study, was burnt at Apia, Samoa. It was conducting a three-year exploration of the Pacific Ocean and, at that time, about a third of the planned cruise was done. Captain James Percy Ault, commander of the ship and director of its scientific staff, died in the accident. The destruction of the *Carnegie* was a serious blow not only to the Carnegie Institution's oceanographic program but also to Vaughan and the Scripps Institution, as there had been an arrangement between J. C. Merriam and Vaughan about the ship's use by the Scripps Institution in 1931 and 1932. Vaughan had made plans for an intensive investigation of the eastern Pacific Ocean, and had already begun to raise $120,000 for the two years' cruise.[60]

The planned exploration on the Carnegie was an ambitious project very important for the Scripps Institution's research program as it would have been the only such large-scale investigation of the open sea. During Vaughan's directorship, Scripps scientists seldom went to the open sea. Since 1917, when Ritter sold the *Alexander Agassiz*, the Scripps Institution did not own a research vessel and only in September, 1925, could it purchase another one. In 1917, the institution's staff was heavily engaged in war-related efforts, and they could enjoy the full support from various government agencies, both federal and state. In that situation, Ritter confessed that the *Alexander Agassiz* was "too large and expensive to operate for the particular phase of the marine investigations we are now entering upon."[61] After Vaughan assumed directorship, he felt the urgent need to buy a research vessel and purchased a former purse seiner, which was then rechristened the *Scripps*. The *Scripps* was, however, a small boat adequate only for coastal surveys and definitely ill-suited for work at open sea. Moreover, use of the vessel was very limited since its operation heavily depended on Erik Moberg's expertise. Other Scripps staff members were not familiar with the work on the *Scripps*, and Moberg's absence during the summers of 1929 and 1930 due to his research with the *Carnegie*

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[60] Raitt and Moulton, *Scripps Institution*, 113; Schlee, *The Edge of an Unfamiliar World*, 265-272.

[61] Raitt and Moulton, *Scripps Institution*, 91.

made it inevitable that there were only few sea-going researches done at Scripps in these two years. Worrisome voices were beginning to be heard both within and outside the institution about the direction of Scripps under Vaughan. The *Carnegie* expedition could have calmed down such critics had it been carried out successfully.

Scripps oceanographers were busy doing their own researches, however, with the data and samples collected by the cooperating institutions, although they had few chances to conduct seagoing investigations. The data were vast and covered a large part of the eastern Pacific. Temperature readings, water samples, and plankton samples were coming to Scripps from the ships of the Navy, the U.S. Coast and Geodetic Survey, and even some commercial ships, while lighthouses on the Pacific coast collected them on shore. For the small number of the Scripps scientists and their assistants, analyzing and drawing meaningful conclusions from them in a timely fashion were not an easy task. They were able to know enough about the parts of the Pacific Ocean where the samples and data were collected. The problem with this style of oceanographic research was that scientists could hardly design and conduct the data gathering process exactly the way they wanted. First, the data given them were collected at certain parts of the ocean and a large part of the Pacific still remained untouched. Those ships sailed and collected data along the main trade routes and, inevitably, much of the given data somewhat overlapped. Also, scientists wanted periodic observation since the condition of a certain area of the sea may vary greatly even in a same day, not to mention seasonal and annual changes. The best way to do it was to have the institution's own vessel large enough to conduct researches in the open sea.

Having been working mainly at the laboratories of the institution, some staff members were feeling that the ideal of field science at Scripps was at stake. In the early years of the institution, Ritter, then director of the San Diego Marine Biological Association, made it clear that he and his colleagues intended to pursue the study of marine biology thoroughly as a field science, as opposed to experimental, laboratory life sciences.[62] Going to the place where marine animals actually lived, and investigating the physical environment as well as the organisms themselves were the essential part of

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[62] For complaints over Vaughan's leadership, see Ronald 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 (2003): 461-500; John A. McGowan, "Sverdrup's Biology," *Oceanography,* 17 (2003): 106-112.

the research at the institution at that time, which the research staff believed to be the only proper way to study marine biology. Now that the institution's scientific work was done more in labs than in the field, those familiar with the old style of Scripps science, especially biologists like Winfred Allen, were thinking that there was something wrong. It was going against the traditional style of scientific practice of the Scripps Institution. Such a criticism added more pressure on director Vaughan.

As the demand for seagoing researches with the institution's own research vessel became evident, Vaughan realized that a new leadership was needed in Scripps. As early as 1932, he began to talk about his intention to retire, and started to search for his successor. Vaughan, now in his mid-sixties, thought himself to be too old for taking an active role in leading intense scientific investigations at sea. In 1934, he even became ill with tuberculosis, which made it necessary for him to stay home for six months. Leaving Scripps may have been a good thing for Vaughan himself as well for another reason. An active scientific researcher, he always felt unhappy at La Jolla where he had piles of administrative duties as director, which interrupted his own work in geology and paleontology. When he was offered the position of Scripps' director in 1923, he accepted it on condition that he should be "permitted to finish up his own oceanographic investigations."[63] However, the duties of the institution's director kept him from spending a satisfactory amount of time on his own research and he often complained of it. Retiring from his position at Scripps, and the University of California, and going back to his former position at the U.S. Geological Survey would certainly give him what he wanted. In the search process, a Norwegian oceanographer Harald U. Sverdrup was finally selected and he took office on September 1, 1936. Vaughan's years in California ended.

7. Conclusion

During his dozen years at the Scripps Institution, Vaughan accomplished many

[63] Raitt and Moulton, *Scripps Institution*, 97-98.

important things not only for his institution but for the science of oceanography in the whole country. Before he went to Scripps, oceanography was hardly an established scientific discipline in the United States, with even its definition and scope not clear. When he left the institution, oceanography had become an acknowledged science just like other scientific fields. Oceanography was firmly institutionalized, at least at the University of California, as an academic field within the university system having a departmental status, and that could not have happened had it not been for T. Wayland Vaughan. During his tenure at Scripps, he did not confine education and research in oceanography within his institution and university, but tried to extend them to a wider circle by playing a major role in building a national and international network.

How does a new scientific field become established and institutionalized? What are the conditions that have to be fulfilled before it can become a scientific discipline? Certainly, there are several things that such new sciences have to achieve before they acquire the academic, social, and political status that older fields enjoy. In the case of oceanography, it was Vaughan who began these things for the new science. Although he did not make the decision to make Scripps an oceanographic institution, it was he who did the rest of the things there. Vaughan defined the science and reconstructed the structure of the institution’s academic force. Scripps became home not only for marine biology or hydrography but for all approaches to the scientific study of the ocean. He added education to the duty of the institution thereby making it both a research and an education unit of the University of California. Thus, Scripps became the first “department of oceanography” in the United States even though it did not possess the official title ‘department.’ Since the late nineteenth century, universities had become the foremost places for science, and scientists. Learned societies, courts of princes, government agencies, all of which once played important roles for scientific development had been relegated to secondary places, and universities now came to occupy the primary position in modern science. Therefore, acquiring a place within the university system became a crucial step for a new science to become firmly established in the modern world. The Scripps Institution existed as a part of the University of California before Vaughan, yet in a very different situation: it was not an institution for oceanography but for ‘biological research’ and it had an intimate relationship with the zoology department in Berkeley. The credit for placing oceanography on a firm footing should, therefore, go to Vaughan and not to his predecessor.

It is true that Vaughan's pioneering work of institutionalizing oceanography largely was confined to the University of California, and it took some time before other American universities followed the example. He and his colleagues at the Scripps Institution of Oceanography, however, represented American oceanography and the presence of those oceanographers and their oceanographic institution informed both scientists and lay people of the new scientific discipline. They also represented the American oceanographic community abroad by actively participating in international scientific meetings. With the activities of the Scripps oceanographers, and their colleagues at other American oceanographic institutions such as the Woods Hole Oceanographic Institution which benefited from the help and advice of Vaughan, oceanography gradually became acknowledged as an established academic science.

Recently, historians of science have been paying attention to oceanography during World War II and its aftermath emphasizing that it made a great contribution to the American war effort and that oceanography itself underwent a substantial transformation into a very different type of science.[64] The tremendous amount of money given to oceanographic research by the federal government, mostly through the navy, made possible the large-scale researches that were unthinkable before. Special emphasis was given to military aspects of oceanography inevitably, causing differentiated support to branch fields of the science. Physical oceanography, particularly marine acoustics, was the most useful field in connection with submarine and anti-submarine warfare against the German navy. The superior position of physical oceanography continued well into the Cold War period. These changes put an indelible imprint on oceanography that continues until the present and, thus, they are no doubt very important in the history of oceanography. It is also important, however, to understand that these things during and after the war could not have happened had oceanography not been institutionalized and established as a scientific discipline. Comparison between the situations during the two

[64] See, for example, Rainger, "Adaptation and the Importance of Local Culture"; Rainger, "Science at the Crossroads: The Navy, Bikini Atoll, and American Oceanography in the 1940s," *Historical Studies in the Physical and Biological Sciences*, 30 (2000): 349-372; Naomi Oreskes, "Laissez-tomber: Military Patronage and Women's Work in Mid-20th-century Oceanography," *Historical Studies in the Physical and Biological Sciences*, 30 (2000): 373-392; Jacob Darwin Hamblin, "Visions of International Scientific Cooperation: The Case of Oceanic Science, 1920-1955," *Minerva*, 38 (2000): 393-423; and Hamblin, "The Navy's "Sophisticated" Pursuit of Science: Undersea Warfare, the Limits of Internationalism, and the Utility of Basic Research, 1945-1956," *Isis*, 93 (2002): 1-27.

world wars makes the point clear. Oceanographic knowledge did not make a big difference in the war effort during the First World War, and the Scripps Institution for Biological Research could provide expertise only in marine biology mainly related to food production. American marine science in the 1910's was not organized into a single academic field and the government and navy did not know where to find the needed scientific assistance. In addition to the obvious fact that the science was much less developed at that time, the poor state of ocean sciences did prevent more direct contributions. Better organized oceanography could contribute more to the war research during the Second World War, and this organization owed much to Wayland Vaughan's effort at the Scripps Institution. Without Vaughan, oceanography could hardly have reached the point of development by the time of the war where it could actually aid the Navy.

CHAPTER 4

Building Oceanography on the American East Coast I: Henry Bigelow, the National Academy of Sciences Committee on Oceanography, and the Woods Hole Oceanographic Institution

In the mid-1920's, the Scripps Institution of the University of California successfully turned into an oceanographic institute during the early years of T. Wayland Vaughan's directorship. Soon after, a move to establish an oceanographic institution on the east coast comparable to Scripps followed with the aim of possessing in the United States major research institutions of oceanography on both the Pacific and the Atlantic coasts.

Aside from the imbalance that existed within the United States between the two coasts, there existed yet another dimension in the consideration to build a central oceanographic institution on the east coast. The fast development of oceanographic research in the European nations was probably the far more important factor in the discussion on the situation of American oceanography. In northern Europe, particularly, oceanographic institutions formed a network for international cooperation in order to solve the problems of the North Sea fisheries. As early as the late nineteenth century, leading scientists in the several different countries arrived at the idea that it did not suffice for each nation to study only a small part of the ocean that it bordered upon, and only by concerted efforts among neighboring countries could the fisheries problem be properly tackled. Well aware of the developments going on at that time in Europe, Americans felt that the United States was lagging behind its European counterparts and that they had to do their share of oceanographic work on the other side of the Atlantic Ocean. They thought that better knowledge of the Western Atlantic, which could be achieved only by more active American participation, would enable the scientific understanding of the whole ocean system.

Considering the apparent gap in the region, at both national and international levels, therefore, it is not so difficult to understand why the desire to improve the situation arose at that time within the oceanographic community in the United States. Building an oceanographic institution on the east coast was, however, a totally new kind of task for it necessarily had to be different from all the existing American scientific institutions, including Scripps, in many respects. Scripps slowly evolved from a humble summer camp into an oceanographic institution, taking more than a quarter century, but the east-coast institution would have to be built in a modern shape from the very start. Moreover, the intellectual, institutional, and political situation on the east coast differed in many ways from that of the west coast, which made it inevitable that the new oceanographic institution had to play a role which had no direct precedent in the United States, as well as in Europe. Scripps Institution's relationship with the state university of California was another problem that prevented it from becoming an appropriate model for the eastern institution. In order to stimulate, influence and coordinate the research and education of ocean sciences at diverse locations and institutions on the east coast, it was far from desirable for the oceanographic institution to be bound up with a particular university or state.

A full scale discussion was necessary, then, on the character, organization, and actual ways to erect the institution. Chapters 4 and 5 will explore the background, some of the main actors, major issues, and aftermath of that discussion around American east-coast oceanography. First, Chapter 4 will begin with the oceanographic activities on the American east coast in the period just preceding the discussion, focusing mainly on Henry Bigelow's scientific career. Then, it will concentrate on the forming of the National Academy of Sciences' Committee on Oceanography. The discussions that took place there, which developed into the final report, will be discussed in Chapter 5. This report was written by the Committee's secretary Henry Bigelow and was submitted to the Academy in 1929. The Committee's activities finally bore fruit in the founding of the Woods Hole Oceanographic Institution in 1930, for which its report played the role of a blueprint. The Report of the Committee on Oceanography is probably the most important non-technical monograph written in the United States in the first half of the twentieth century and, therefore, the next chapter will cover it in some detail.

With the founding of the Woods Hole Oceanographic Institution, American oceanographers, especially those in the northeastern part of the United States, now possessed a much more stable means by which to study the vast Atlantic Ocean. And in the long run, it indeed filled the gap in the national and international picture of oceanographic research institutions quite successfully. Its success and uniqueness can only be explained when we understand the previous situation of the east-coast region in terms of ocean sciences, the motives of the people who were involved with the discussion, and the context within which the institution would later operate.

1. Henry Bigelow and His Oceanographic Research at the Gulf of Maine

It would be a total misunderstanding if we think of east-coast oceanography as non-existent before the founding of the Woods Hole Oceanographic Institution. There was, in fact, a very active tradition of ocean research on the east coast that can be dated back to the mid-nineteenth century. The most recent research project in oceanography there, and also the most important one perhaps, was the joint study of the Gulf of Maine region by the United States Bureau of Fisheries and the Museum of Comparative Zoology of Harvard University, led by Harvard oceanographer Henry Bryant Bigelow. In the late 1920's, when the National Academy of Sciences' Committee on Oceanography was discussing the problems of American oceanography, Bigelow was considered by many as the foremost American oceanographer, at least on the east coast.

Henry Bigelow's lifelong zeal for the science of the sea began in 1901 when he decided to participate in Alexander Agassiz's expedition to the Maldives. Agassiz had long been interested in the study of oceans and marine life, and he was deeply interested in the problem of coral reef formation.[1] Having accumulated a great fortune through his successful copper mine business, he could easily afford to carry out scientific expeditions to the open seas in the Pacific and the Atlantic oceans. The close relationship he maintained with the U.S. Coast and Geodetic Survey and the U.S. Fish Commission (later the Bureau of Fisheries) allowed him to make use of the government's survey vessels, especially the fisheries steamship *Albatross*. His wealth enabled this gentleman scientist to pay for the fuel needed for the lengthy cruises. In early 1901, he was

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[1] For a brief biography of Alexander Agassiz and his oceanographic activities, see George Lincoln Goodale, "Alexander Agassiz," *National Academy of Sciences Biographical Memoirs*, Vol. VII (1913): 288-305.

planning another scientific trip to the Maldive Islands in the Indian Ocean, and the news reached the young Bigelow who was readily attracted by it.

Henry Bigelow, who was born to a wealthy Bostonian family, became familiar with wildlife and the natural world early in his life by engaging in sport activities.[2] It was natural for him to become interested in natural history when he entered Harvard in 1897 at the age of 17. Before going to college, he already had a chance to study natural history under Alpheus Hyatt at the Boston Natural History Museum. But it was in 1901, in his senior year, when he first joined Alexander Agassiz's expedition to the Maldive Islands that he truly became involved in the study of marine zoology. Having heard about Agassiz's planned trip, Bigelow visited him one day and asked if he could join the expedition. And "His answer which was "yes,"" wrote Bigelow, "not only initiated my close association with Mr. Agassiz which continued until his death in 1910, but which greatly influenced my subsequent scientific career."[3] Bigelow entered Harvard's graduate school where he worked with professors G. H. Parker and E. L. Mark and studied a wide range of zoological subjects, including the sense of hearing in goldfish and even cytology.[4] But it was the study of marine biology that became his main field in his early scientific career, especially the study of medusae which he first encountered as an object of scientific work during his first cruise with Agassiz.

During the Maldive expedition, Agassiz assigned to Bigelow the collection of medusae, which became his main specialty as a marine zoologist for more than a decade, or perhaps longer.[5] After the research trip, Bigelow worked at the Museum of

[2] Henry B. Bigelow, *Memories of a Long and Active Life* (Cambridge: Cosmos Press, 1964); Alfred C. Redfield, "Henry Bryant Bigelow," *National Academy of Sciences Biographical Memoirs*, Vol. 48 (1976): 50-80.

[3] Bigelow, *Memories*, 9.

[4] Henry B. Bigelow, "The Sense of Hearing in the Goldfish Carassius Auratus L.," *American Naturalist*, Vol. 38, No. 448 (1904): 275-284; Bigelow, "Studies on the Nuclear Cycle of Gonionemus Murbachii A. G. Mayer," *Bulletin of the Museum of Comparative Zoölogy at Harvard College*, Vol. 48, No. 4 (1907): 287-399.

[5] Bigelow, "Medusae from the Maldive Islands," *Bulletin of the Museum of Comparative Zoology*, 39 (1904): 245-269; Bigelow, "Coelenterates from Labrador and Newfoundland, Collected by Mr. Owen Bryant from July to October, 1908," *Proceedings of the U.S. National Museum*, 37 (1909): 301-320; Bigelow, "Cruise of the U.S. Fisheries Schooner *Grampus* in the Gulf Stream During July, 1908, with description of a New Medusa (*Bythotiaridae*)," *Bulletin of the Museum of Comparative Zoology*, 52 (1909): 195-210; Bigelow, "Biscayan Plankton Collected During a Cruise of H.M.S. *Research*, 1900. XIII. The Siphonophora," *Transactions of the Linnean Society of London* (2nd ser., Zoology), 10 (1911): 337-358; Bigelow, "Scientific

Comparative Zoology studying several topics in zoology and natural history but mainly concentrating on the study of medusae and other coelenterates. In 1906, he received his Ph.D. degree from Harvard and was appointed Assistant at the Museum, followed by the appointment as Curator of Coelenterates seven years later. Bigelow's study of marine biology, coelenterates in particular, depended heavily on Agassiz's series of oceanic expeditions.[6] He was a member of the expedition to the Eastern Pacific in 1904 and 1905, and to the West Indies in 1907. During the expedition in the Eastern Pacific, Bigelow became acquainted with Charles Kofoid who was then teaching at the zoology department of the University of California and an active member of the San Diego Marine Biological Association.[7] Bigelow could maintain for a long time a close relationship with Kofoid and the scientific staff of the Association, and later the Scripps Institution, many of whom were Agassiz's former students.

As Bigelow became more interested in oceanography in the 1910's he spent less of his working time on the study of the coelenterates, but he did not give up the work altogether. Rather he continued it until at least 1940, when he published his last paper on medusae.[8] Once Bigelow established his reputation as a world-class expert on the

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Results of the Philippine Cruise of the Fisheries Steamer *Albatross*, 1907-1910. 22. Preliminary Account of One New Genus and Three New Species of Medusae from the Philippines," *Proceedings of the U.S. National Museum*, 43 (1912): 253-260; Bigelow, "Medusae and Siphonophorae Collected by the U.S. Fisheries Steamer *Albatross* in the Northwestern Pacific, 1906," *Proceedings of the U.S. National Museum*, 44 (1913): 1-119.

[6] For example, see Bigelow, "Report on the Scientific Results of the Expedition to the Eastern Tropical Pacific, in Charge of Alexander Agassiz, by the U.S. Fish Commission Steamer Albatross, from October, 1904 to March, 1905, Lieut. Commander L. M. Garrett, U.S.N., Commanding. XVI. The Medusae," *Memoirs of the Museum of Comparative Zoology*, 37 (1909): 243 pp.; Bigelow, "Report on the Scientific Results of the Expedition to the Eastern Tropical Pacific. XXIII. The Siphonophorae," *Memoirs of the Museum of Comparative Zoology*, 38 (1911): 173-402; Bigelow, "Reports on the Scientific Results of the Expedition to the Eastern Tropical Pacific. XXVI. The Ctenophores," *Bulletin of the Museum of Comparative Zoology*, 54 (1912): 369-404.

[7] See Chapter 2 for Kofoid's career at the San Diego Marine Biological Association.

[8] Bigelow, "Fauna of New England. 12. List of the Medusae, Craspedotae, Siphonophorae, Scyphonomedusae, Ctenophorae," *Occasional Papers of the Boston Society of Natural History*, 7 (1914): 1-37; Bigelow, "Notes on the Medusan Genus *Stomolophus* from San Diego," *University of California Publication in Zoology*, 13 (1914): 239-241; Bigelow, "*Epheretmus*, a New Genus of Trachomedusae," *Proceedings of the U.S. National Museum*, 49 (1915): 399-404; Bigelow, "*Halimedusa*, a New Genus of Anthomedusae," *Transactions of the Royal Society of Canada*, ser. 3, 10 (1916): 91-95; Bigelow, "Some Medusae and Siphonophorae from the Western Atlantic," *Bulletin of the Museum of Comparative Zoology*, 62 (1918): 365-442;

coelenterates, samples and collections were sent to him from both within and outside the United States, and this system made it possible for him to continue his research and publication without having to go out to the sea for collecting. But it is clear that his main scientific interest moved somewhat away from that subject after about 1910. This timing coincided with the death of Alexander Agassiz. When Agassiz died in 1910, things changed abruptly for Bigelow whose marine studies depended so much on the resources made available to him by his mentor. Now, Bigelow could not afford the expensive ventures on the open seas. Although he continued to work with the large collections of marine animals, working only inside the laboratories of the Museum of Comparative Zoology was not something an outdoorsman like Bigelow could really enjoy. He needed a ship for his own research!

There was something more to Bigelow's desperate wish for a research vessel. In the several years around 1910, he underwent a substantial change in the way he conceived the oceans as a subject of scientific study. While he was having difficulty going out to the sea, he had been carefully watching the progress of a new line of oceanic study going on in Europe, especially by the Scandinavian scientists.[9] To understand the yearly fluctuations in the fishery yields they began the study of the life histories of economic fishes, such as herring and cod, and found out that it was extremely important to understand the physical properties of the sea, most significantly

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Bigelow, "Hydromedusae, Siphonophores and Ctenophores of the Albatross Philippine Expedition. Contributions to the Biology of the Philippine Archipelago and Adjacent Regions," *Bulletin of the United States National Museum*, no. 100, 1 (1919): 279-362; Bigelow, "Medusae and Ctenophores from the Canadian Arctic Expedition, 1913-1918," *Report of the Canadian Arctic Expedition, 1913-1918, 8(H)* (1920): 1-22; Bigelow, "Scyphomedusae from the Arcturus Oceanographic Expedition," *Zoologica*, 8 (1928): 495-524; Bigelow, "Siphonophorae from the Arcturus Oceanographic Expedition," *Zoologica*, 8 (1931): 525-592; Bigelow and Mary Sears, "H2. Siphonophorae," *Report of the Danish Oceanographic Expeditions, 1908-10, to the Mediterranean and Adjacent Seas, 2 (Biology)* (1937): 144 pp.; Bigelow, "Plankton of the Bermuda Oceanographic Expedition. VIII. Medusae Taken During the Years 1929 and 1930," *Zoologica*, 23 (1938): 99-189; Bigelow, "Eastern Pacific Expeditions of the New York Zoological Society. XX. Medusae of the Templeton Crocker and Eastern Pacific "Zaca" Expeditions, 1936-1938," *Zoologica*, 25 (1940): 281-321.

[9] For example, Bigelow's comments on the work of the Norwegian research vessel *Michael Sars* show that he had been carefully following the European oceanographic programs. Bigelow, "The Work of the *Michael Sars* in the North Atlantic in 1910," *Science*, 34 (1911): 7-10; Bigelow, "Fishes and Medusae of the Intermediate Depths. A Note on the Work of the *Michael Sars*," *Nature*, 86 (1911): 483.

oceanic currents that carried fish eggs and larvae to distant places. Bigelow came to understand that the ocean is a complex system and that the life phenomena there could not be attacked without the help of physical oceanography. He also met Sir John Murray, eminent British oceanographer of the *Challenger* expedition and a member of the *Michael Sars* expedition, during his visit to Harvard in 1910. Murray probably encouraged Bigelow to embark on an oceanographic study of his own at the Northwestern part of the Atlantic Ocean.[10]

In early 1912, Bigelow proposed an oceanographic survey of the Gulf of Maine as a joint project between the Museum of Comparative Zoology and the U.S. Bureau of Fisheries.[11] This was obviously a new line of study that had not been attempted before in the Atlantic coast of the United States. Ultimately, it aimed at contributing to the solving of the problem of yearly fisheries fluctuations and declining yields. Adopting the European precedent, however, Bigelow suggested that scientific study of the physical movements of sea water, in addition to the study of planktons and fishes, was necessary for that purpose although it might seem too far from being directly practical. This idea was supported by other scientists who shared with Bigelow the belief in the usefulness of basic oceanographic work for the problem of fisheries. For example, J. S. Kingsley of the Harpswell Laboratory, Tufts College, wrote “Suggestions for the Work of the Bureau of Fisheries in Casco Bay in the Summer of 1912” in November, 1911, where he stated:

> Practically nothing is known of the oceanography of the Gulf of Maine. Considerable is known of its depths, its banks, and, in spots, of its fauna and flora, but aside from these matters little is known concerning it. A more accurate and extensive knowledge of some of the other points may have a great and immediate value for the fisheries of Maine and other states. As you know, the work of the International Commission has proved of the greatest value to the fisheries of northern Europe and there is no reason why the same methods would not be applicable here. It has been shown that there is a direct relation between the temperature

[10] Redfield, “Bigelow,” 54; Bigelow, *Memories*, 23.

[11] For a full discussion of Bigelow’s Gulf of Maine studies, see Jeffrey P. Brosco, “Henry Bryant Bigelow, the U.S. Bureau of Fisheries, and Intensive Area Study,” *Social Studies of Science*, 19 (1989): 239-264.

> and salinity and the spawning times and places of several fishes. A similar relation exists between the abundance of plankton and other fishes, such as the mackerel and herring. Farther the matter of previous sunlight and transparency of the water is important, as the diatomaceous plankton is directly dependent on sunlight; this affects the abundance of copepods, and these have a direct relation to the herring.[12]

Fortunately for Bigelow, the Bureau of Fisheries accepted Bigelow's scheme and placed the Fisheries schooner *Grampus* at his disposal for the summer of 1912. It was possible because of Alexander Agassiz's personal network and Bigelow clearly knew it for he wrote that George M. Bowers, U.S. Commissioner of Fisheries, "certainly would not have done [so] had he not known of my close association with Mr. Agassiz."[13]

The joint oceanographic exploration of the Gulf of Maine was carried out until 1924. The long-term project had three separate, but ultimately interconnected, areas of concentration: physical oceanography, plankton study, and the study of fishes. Bigelow oversaw the whole project, but was particularly in charge of the first two areas and the Bureau of Fisheries biologist W. W. Welsh of the last. During the study, Bigelow, his colleagues, and the crew of the ships visited 350 stations and made measurements of temperature and salinity and made 10,116 tow-net hauls. Moreover, they repeatedly worked at 137 stations where "serial measurements of temperature were obtained (usually with corresponding determination of the salinity)." The result was, Bigelow himself wrote, that "oceanographically, the Gulf of Maine is better known than is any other comparable area of the ocean, the survey of which have been carried out by a single agency."[14] In 1924, three final reports were published, for the three areas of research, all written by Bigelow.[15] Welsh was originally responsible for the writing of

[12] J. S. Kingsley, "Suggestions for the Work of the Bureau of Fisheries in Casco Bay in the Summer of 1912" (November 25, 1911), *Henry Bryant Bigelow Papers*, Harvard University Archives.
[13] Bigelow, *Memories*, 23.
[14] Ibid., 23-24.
[15] Bigelow, "Plankton of the Offshore Waters of the Gulf of Maine," *Bulletin of the U.S. Bureau of Fisheries*, Vol. 40, Part 2 (1924): 1-509; "Physical Oceanography of the Gulf of Maine," *Bulletin of the U.S. Bureau of Fisheries*, Vol. 40, Part 2 (1924): 511-1027; Bigelow and William W. Welsh, "Fishes of the Gulf of Maine," *Bulletin of the U.S. Bureau of Fisheries*, Vol. 40, Part 1 (1924): 1-567.

the report on fishes, but his unexpected death made it necessary that Bigelow finish it.

The Gulf of Maine study was apparently different from Agassiz's style of studying the oceans, which usually covered a huge area of the sea often in distant locations from the coasts of the United States. Bigelow decided to confine his oceanographic project mainly within a single, comparatively small region because of several reasons, the first of which being that he could not manage the expensive long cruises to dispersed areas in many parts of the world's large oceans. A significant factor was that Bigelow had by then noticed the shift in the mode of oceanographic research begun in Europe. Having acquired enough data through decades of oceanic expeditions, scientists now had a rough picture of the physical and biological features of the global ocean system. A point had been reached, they thought, when more detailed local information and causal analyses of specific areas of the sea would yield more productive results than the traditional, long expedition cruises. The "intensive area study," dominant methodology of the participants of the International Council for the Exploration of the Sea (ICES), was first tried in the United States by William Ritter in California several years earlier.[16] Henry Bigelow, well aware of the events going on both in Europe and in California, decided to adopt this research method on the east coast, and chose the Gulf of Maine as an ideal location for the project. Why, then, did Bigelow choose the Gulf of Maine? He enumerated several reasons for his decision:

> We chose the Gulf of Maine as our first field of work partly because of its important fisheries, partly because it was nearly virgin ground so far as sub-surface temperatures, salinities and plankton were concerned, but chiefly because, being a partially isolated area, a comparatively complete survey could be made in the time at our disposal. The stations were planned to include Massachusetts Bay, the deep basin off Cape Ann and Cape Cod, the coastal waters and off-shore banks along the coast of Maine, and a line from Cape Elizabeth to Cape Sable, while a week was spent trawling in and near Casco Bay in cooperation with the Harpswell Marine Laboratory.[17]

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[16] See Brosco, "Henry Bryant Bigelow" for the "intensive area study" method in oceanography. See Chapter 2 for Ritter's intensive research program in the California coast.

[17] Henry B. Bigelow, "Oceanographic Cruises of the U.S. Fisheries Schooner "Grampus" 1912-

In addition to the region's importance for the fishery industry, its adequate natural conditions for intensive oceanographic study were certainly taken into consideration.

A combination of physical and biological study of the sea with the aim of contributing to the fishery industry, the Gulf of Maine study was no doubt an ICES style of approach. Physical oceanography was, thus, a very important part of the whole project, important not only in itself but also for the biological study. Indeed, one of the main purposes of the research from the beginning was to find out "the source of the cold water of the Gulf of Maine," which could be known only when the current system of the gulf was fully understood.[18] It is interesting that Bigelow, a biologist who had no special training in physics or mathematics, led the Gulf of Maine research project. It certainly was not a job appropriate for a marine biologist in a traditional sense, but rather fit for someone who could oversee the whole marine scientific work with general knowledge and experience in many fields of oceanography. It was a huge metamorphosis for Bigelow in fact, and his friends and colleagues certainly noticed it, no matter whether they welcomed it or not. British marine biologist Edward T. Browne, an authority on medusae and hydroids, wrote to Bigelow in 1914 that "I notice that you are becoming an oceanographer." He continued, "but hope that you will keep medusae as your special subject and never forget to bottle specimens."[19] This older colleague who had a tie to the Marine Biological Association's laboratory in Plymouth had long been communicating and cooperating with Bigelow regarding their common interest, medusae. He probably did not want to lose this younger medusae researcher to oceanography.

Bigelow's study of the physical properties of the ocean closely followed the examples set by the Scandinavian oceanographers. His foremost interest during the Gulf of Maine study was to understand its current system. He wrote that "[d]uring these explorations, it has become increasingly evident that the key to many puzzling phenomena, biologic as well as physical, is to be sought in the circulation of the water on the continental shelf."[20] For that purpose, he adopted as the primary methodology

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1913," *Science*, Vol. 38, No. 982 (1913): 599-601. The Harpswell Marine Laboratory was where J. S. Kingsley of Tufts University worked as director.

[18] Kingsley, "Suggestions"; Brosco, "Henry Bryant Bigelow," 239.

[19] Letter from Edward T. Browne to Henry B. Bigelow (July 4, 1914), *Henry Bryant Bigelow Papers*, Harvard University Archives.

[20] Henry B. Bigelow, "Oceanic Circulation," *Science*, Vol. 62, No. 1606 (1925): 317-319.

hydrodynamics, an innovative scientific field developed by Vilhelm Bjerknes and made applicable to the oceanic phenomena by Bjørn Helland-Hansen and Johan Sandström. The theory and the derivative equations allowed ocean scientists to get the velocity of currents from temperature and salinity data of water masses.[21] Therefore, during the Gulf of Maine studies, Bigelow's work in the area of physical oceanography mainly involved gathering data of temperature and salinity from the stations within and outside the gulf, preferably at the same ones repetitively in different seasons and years. But other methods were employed, too. "The circulation of the sea," wrote Bigelow, "may be studied by indirect methods and by direct; both are being employed."[22] Direct methods referred to the use of drift bottles and the plankton study. Drift bottles retrieved and the distribution of several species of planktons and fish larvae confirmed the validity of hydrodynamic method. As a biologist by training, Bigelow was adept in collecting and identifying marine planktons collected from many different places at sea, and it allowed him to chart the movement and drift of fish larvae and small animals, which confirmed the movement of water masses known to him by physical methods. In this way, he compensated for his deficiency in mathematical training with his biological expertise.

The Gulf of Maine study was a phenomenal achievement for American oceanography. Nevertheless, it clearly revealed problems and weaknesses of American oceanography, particularly on the east coast. For Bigelow, the most serious problem was the difficulty of having access to ships appropriate for oceanographic research. The Gulf of Maine study was carried out uninterrupted until 1924 except for the period of World War I during which Bigelow worked as navigation officer for the U.S. Navy. The purposes and methodologies of the project required that much of the work be done at sea repetitively on a regular basis. As a result, Bigelow and colleagues could arrive at the understanding of seasonal and yearly variations in the physical and biological properties of the area. Yet, throughout the whole period Bigelow had a hard time with the ships;

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[21] Brosco, "Henry Bryant Bigelow," 241-243; Eric L. Mills, "The Oceanography of the Pacific: George F. McEwen, H. U. Sverdrup and the Origin of Physical Oceanography on the West Coast of North America," *Annals of Science*, 48(1991): 241-266; Susan Schlee, *The Edge of an Unfamiliar World: A History of Oceanography* (New York: E.P. Dutton, 1973), 170-205. See also Robert Marc Friedman, *Appropriating the Weather: Vilhelm Bjerknes and the Construction of a Modern Meteorology* (Ithaca: Cornell University Press, 1989) for a scientific biography of Bjerknes.

[22] Bigelow, "Oceanic Circulation," 317-319.

both getting a ship at a right time and getting an appropriate one were difficult. Research vessels were mostly provided to him by the Bureau of Fisheries. In fact, obtaining a research vessel was the most important reason for the cooperation with the federal agency on Bigelow's part. But the Bureau also had difficulties with its survey ships. With all of its ships running in a tight schedule for their original missions, it was hard for the Bureau officials to spare a good one for Bigelow's project every time.

The fisheries steamer *Albatross* was by far the best suited for scientific work at sea. Because of its superiority, however, it was almost always needed for the Bureau's other missions, and Bigelow could only seldom use it. Instead, several different ships were provided to him according to the schedules of the Bureau's ships and the characters of work each season.

> Commenced on the schooner *Grampus*, and continued to date on the fisheries steamers *Albatross*, *Halcyon* and *Fish Hawk*, the exploration has resulted in perhaps as detailed a knowledge of the distribution of temperature and of salinity, regionally, with depth, and with the change of the seasons as can be claimed for any other part of the sea of like area.[23]

The fisheries schooner *Grampus* which was the first vessel to be used in July 1912 was also the one most often used for the whole Gulf of Maine study. From the beginning, Bigelow complained that it was not appropriate as an oceanographic research vessel in many respects.

> In a sailing vessel, which the *Grampus* is primarily in spite of a small auxiliary gasoline engine, oceanographic work is necessarily carried on under difficulties. But there is no steamer available. And fortunately we have enjoyed such exceptionally fine weather on both cruises that we worked to better advantage than might have been expected.[24]

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[23] Bigelow, "Oceanic Circulation."
[24] Bigelow, "Oceanographic Cruises of the U.S. Fisheries Schooner "Grampus" 1912-1913," 599-601.

The *Grampus* was far from suitable for oceanographic surveys, yet Bigelow had no other choice but to use it somehow. Each time he went to sea on it, he tried to improve its conditions gradually by installing instruments and devices with the support of the Bureau of Fisheries.

By 1924, it became apparent that the Gulf of Maine study was coming to an end. It ended unexpectedly for Bigelow when the Bureau of Fisheries vessels *Albatross* and *Grampus* became unavailable. Now that the vessels became old the Bureau made a decision to give up maintaining *Albatross*, and several years later it sold *Grampus* as well. Having supported Bigelow's investigation for years in the belief that scientific study of the ocean and its inhabitants was the best way to solve the fisheries problems, the Bureau now turned its main focus to wholly different kinds of investigation—to the studies of marketing and processing of fish. In other words, the research strategy of the Bureau moved from production in the sea to later processes on land, which seemed to provide a more certain way to boost the industry.[25] Bigelow also thought that a time was reached when enough was achieved from the Gulf of Maine to enable him to write the reports. Yet, he knew that there was much more to be learned about the Gulf, and certainly had no intention to halt the investigation entirely at that point of time. Without the firm cooperation with the Bureau that he had been able to enjoy for the past twelve years, Bigelow had to look for other possible sources of support, especially a support of providing him with a research vessel. Given the characteristics of Bigelow's oceanographic research, an appropriate ship was indispensable, and without one he could not but continue doing nothing new with oceanography. He desperately sought for a new patron and a vessel that could be available immediately, but only in vain.

Despite the seeming impossibility to secure an oceanographic research vessel, he did not give up the idea of doing a follow-up study of the Gulf of Maine altogether. He sought for chances to continue the work and, finally, he included the Gulf of Maine study in the research plans of the nascent Woods Hole Oceanographic Institution in the early 1930's. Ironically, the success story of Henry Bigelow's Gulf of Maine study

[25] Brosco, "Henry Bryant Bigelow," 263, n. 68. For a brief history and policies of the federal fisheries agency, see Theodore Whaley Cart, "The Federal Fisheries Service, 1871-1940: Its Origins, Organization, and Accomplishments," *Marine Fisheries Review*, 66:4 (2004): 1-46; and Michael L. Weber, *From Abundance to Scarcity: A History of U.S. Marine Fisheries Policy* (Washington, D.C.: Island Press, 2002).

between 1912 and 1924 was at the same time a story of failure for American oceanography in the 1920's. Its story revealed the weaknesses and fundamental problems of American oceanography that its participants and advocates were to struggle in the coming years to overcome.

2. Frank Lillie, Wickliffe Rose, and the National Academy of Sciences' Committee on Oceanography

In the same year that Bigelow's Gulf of Maine study ended, an important discussion for the future of American oceanography began, silently and privately, in another part of the country. Wickliffe Rose, then president of the General Education Board, had a conference in 1924 with Frank Lillie in Chicago to talk on general issues of American agriculture and biology.[26] At that time, Lillie was chairman of the zoology department at the University of Chicago and director of the Marine Biological Laboratory at Woods Hole, Massachusetts. Their discussion continued and from the next year their talk focused on the state of oceanography in the United States. Rose was looking for a way for the General Education Board to contribute to the welfare of the United States, and was especially interested in agriculture. Lillie was interested in developing new lines of biological research connected in some ways to his two ongoing enterprises in Chicago and Woods Hole using the potential funding from philanthropy. Rose and Lillie found a middle ground in the fisheries studies and oceanography. As a leader of marine biology in America, the MBL's director knew the importance of ocean science not only in a biological sense but also in general. Rose, on the other hand, understood that the science of the sea would eventually contribute to the development of one of the nation's important industries, fisheries, and increase the food supply for the

[26] Frank R. Lillie, *The Woods Hole Marine Biological Laboratory* (Chicago: University of Chicago Press, 1944), 177-191; Harold L. Burstyn, "Reviving American Oceanography: Frank Lillie, Wickliffe Rose, and the Founding of the Woods Hole Oceanographic Institution," in Mary Sears and Daniel Merriman, eds., *Oceanography: The Past* (New York: Springer-Verlag, 1980), 57-66; Roger Revelle, "The Oceanographic and How It Grew," in Sears and Merriman, *Oceanography: The Past*, 10-24.

American people.

Having agreed upon the main theme of promoting the science of oceanography and fisheries studies in America, they now wanted to discuss it openly and officially in order to take concrete actions. Rose discussed the matter with John C. Merriam, president of the Carnegie Institution of Washington, and Vernon Kellogg, chairman of the National Research Council, after which they arrived at the idea that it was best to form a committee that would be able to deal with the plan further. Then the two men soon agreed to present the plan to the National Academy of Sciences, and at the meeting in April, 1927 the Academy in turn decided "That the President of the Academy be requested to appoint a Committee on Oceanography from the Sections of the Academy concerned to consider the share of the United States of America in a world-wide program of Oceanographic Research and report to the Academy."[27] The Committee was immediately formed with Lillie as its chair. The Committee on Oceanography of the National Academy of Sciences consisted of William Bowie (U.S. Coast and Geodetic Survey), E. G. Conklin (Princeton University), B. M. Duggar (University of Wisconsin), John C. Merriam (Carnegie Institution of Washington), T. Wayland Vaughan (Scripps Institution of Oceanography), and Frank Lillie as its members. Later, Arthur L. Day (Carnegie Institution) was added to the Committee, and Henry Bigelow also joined it as the secretary. The "old boy network," to use Roger Revelle's phrase, evolved into an official committee at the national level.[28]

The committee carried out its task most rigorously during the summer of 1928, from July 28 to August 25, when it invited notable figures in the field of oceanography from within the United States and abroad to a discussion of issues of concern to the committee. Invited guests included Harald U. Sverdrup of the Geophysical Institution of Bergen, Norway, who from his experience gave valuable advice on the committee's issues. The members studied and discussed the ongoing researches in many fields of ocean sciences, the main problems of oceanography that scientists were then trying to solve, the existing institutions devoted, fully or in part, to oceanography and fisheries science in European countries and in North America, and the state of American oceanography. Having arrived at the understanding that the United States lagged far

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[27] *Annual Report of the National Academy of Sciences*, 1926-1927. Cited from Lillie, *The Woods Hole Marine Biological Laboratory*, 177.
[28] Revelle, "The Oceanographic," 11.

behind the European countries, especially those participating in the ICES, and that the situation on the east coast was far worse than the west, the committee sought to find measures to remedy the problems.

Following the intense work during the summer, the Committee on Oceanography commissioned its secretary Henry Bigelow to write a report that was to be submitted to the National Academy of Sciences. Bigelow spent a year working full time on writing the "Report on the Scope, Problems and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies" which was submitted to the Academy in November, 1929. This report contained Bigelow's, and the committee's other members' understanding of the problems of American oceanography and the remedies to bring it back on the right track for its future proliferation.[29] Most of all, it contained the recommendation of "the establishment of a well-equipped oceanographic institution in a central location on the Atlantic Coast." This recommendation was readily accepted and, as a result, the WHOI was established in 1930. Funding came from the Rockefeller Foundation, from which the marine stations in Bermuda, Puget Sound, and the Scripps Institution also benefited. The Committee on Oceanography afterwards commissioned T. W. Vaughan and T. G. Thompson of the University of Washington to write reports on "International Aspects of Oceanography" and "Oceanography in Universities," respectively. In 1938, a year after Vaughan's report was published, the Committee disbanded having concluded that its mission was complete.[30]

Frank Lillie began his account of the Woods Hole Oceanographic Institution by remarking that "Unlike the Marine Biological Laboratory, the Woods Hole Oceanographic Institution, its sister-institution, sprang full fledged into existence. However, it had a rather prolonged period of incubation."[31] That period of six years was still very short compared with the time needed for the MBL or the Scripps Institution of Oceanography to grow into their mature forms. How, then, could it happen so promptly for the WHOI? What were the factors that made it possible? It is necessary to take a

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[29] Henry B. Bigelow, "Report on the Scope, Problems and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies," Report of the Committee on Oceanography of the National Academy of Sciences, Frank R. Lillie, Chairman. 1929.

[30] Lillie, *The Woods Hole Marine Biological Laboratory*, 179.

[31] Ibid., 177.

closer look into the backgrounds and motives of the main actors of the story.

Wickliffe Rose was head of both the International Education Board and the General Education Board from 1923 to 1928.[32] He was previously chair of the International Health Board, and was deeply involved in the reconstruction of Europe after the Great War. His main field of interest was public health and medical education and, through his position and influence within the Rockefeller philanthropy, he contributed to building centers of medical and scientific education in European countries. He believed in the active role of science and medicine in society, and was confident that research was the best way of training scientists and doctors. Therefore, his solution to the ruins of European countries was to build regional centers of science and medicine which would be able to contribute to the revival of the larger areas surrounding them. Rose was not unique in such an approach. His ideas and beliefs represented the wider tendency to which many business leaders, officials of philanthropic foundations, and scientists in the 1910's and 1920's belonged. They believed in the power of science in changing social conditions and bringing about economic welfare. Therefore their programs focused on building institutions where future scientists were educated by engaging in research. Rose had close contacts with leading American scientists who also shared many of those ideas. Particularly, those at the National Research Council, such as Robert Millikan, frequently discussed these issues with Rose, and it is very probable that their talk influenced his thoughts.

What he did in Europe through the International Health Board and the International Education Board, he wanted to do also in the United States. In this respect, it is not difficult to understand that the project of improving oceanography in the United States initiated by Rose eventually ended up with the establishment of an oceanographic institution, a regional center of research and education on the east coast. At the beginning, Rose first paid his attention to traditional industries like agriculture, forestry, and fisheries for possible programs of the General Education Board, and while talking with Lillie, he found out that there was an area of overlap between his interests and the

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[32] Robert E. Kohler, "Science and Philanthropy: Wickliffe Rose and the International Education Board," *Minerva*, 23:1 (1985): 75-95. For a brief biography of Rose, see Simon Flexner, "Wickliffe Rose: 1862-1931," *Science*, 75 (1932): 504-506. See also Kohler, *Partners in Science: Foundations and Natural Scientists, 1900-1945* (Chicago: University of Chicago Press, 1991).

needs of the scientific community. Rose was interested in the fisheries because of its economic importance and practical benefits whereas Lillie's interest was mostly scientific. Lillie, who had studied marine biology for a long time, found fishery studies an attractive field for biological scientists. He was not new to the field of fisheries studies having worked at an institution which neighbored the laboratory of the Bureau of Fisheries in Woods Hole for many years as student, visiting researcher, and then director. As an embryologist, he was also familiar with the work that was going on at the Bureau's laboratory which mainly dealt with artificial hatchery and fish culture. Yet the Bureau's scientific work, which overemphasized the practical side of fisheries studies was obviously never satisfactory to Lillie and other marine biologists. Lillie must have thought that more basic research of the biology of marine organisms including fish and of the marine environment would greatly benefit the work of fishery scientists, and that that was exactly what biologists, and hydrographers perhaps, could and would happily do if adequate support was given by the General Education Board.

For Rose, Lillie was not the only source of inspiration. His interest in fisheries initially grew partly because of an influence from the British biophysicist William Bate Hardy, F.R.S. who worked for the Department of Scientific and Industrial Research and was chairman of the advisory committee on fisheries of the United Kingdom.[33] He persuaded Rose "both on the importance of fisheries to agriculture and of fundamental science to fisheries." Then his conference with Lillie in Chicago helped Rose to make the decision to support fishery studies in the United States as the General Education Board's project. In July, 1925, he made an intense trip to visit scientific institutions throughout the North American continent to see the state of marine scientific research in the United States. He was especially impressed at the work of the Biological Board of Canada's Atlantic Biological Station at St. Andrews, New Brunswick, which contrasted greatly with the poor situation in most of the stations in the United States. When he returned, he was now confident of the usefulness of scientific work for the practical needs of fisheries and was also well aware of the need to improve American marine sciences.

Another factor that reinforced Rose's interest in the science of the sea was Henry Bigelow's request for a research vessel. At that time, Bigelow was desperately

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[33] Burstyn, "Reviving American Oceanography," 60-63.

looking for ways to secure ships to continue his oceanographic work at sea, with great difficulty. Having heard about the possibility of obtaining support from the General Education Board for oceanographic research programs, Bigelow was quick to approach Rose with his plan for which a suitable ship was indispensable. Rose responded with a demand of a detailed report, and Bigelow promptly submitted one to him "On work in Oceanography which can be accomplished by a suitably equipped ship" in 1925, which certainly did appeal to the director of the General Education Board.[34] The idea of purchasing an oceanographic vessel soon evolved in Rose's mind into a plan for a full-scale research institute, because he thought that maintaining a ship would necessarily require operating personnel and supporting organization, as well as a suitable facility.[35] An experienced administrator that he was, Rose had the ability to think about things that scientists like Bigelow could hardly see. Bigelow later joined the Committee on Oceanography as secretary and had chances to represent his demands.

3. Conclusion

The forming of the Committee on Oceanography was a result of a few individuals' realization that American oceanography on the east coast desperately needed an institutional support. What kind of support would be the most useful had yet to be found out, and that was exactly what the members of the committee were commissioned to do. Among the participants, some had a broad view on the development of American science as a whole and the place of ocean sciences within it, while others had actual experiences of carrying out scientific researches at sea. Coming from different backgrounds, these people had a very good grasp of one or two aspects of the problem they were to deal with, but necessarily had to learn from one another, and from outside

[34] Henry B. Bigelow, "On Work in Oceanography Which Can Be Accomplished by a Suitably Equipped Ship," Fall 1925, Rockefeller Archive Center. Cited from Burstyn, "Reviving American Oceanography," 66, n. 21.

[35] Ibid.; Susan Schlee, "The R/V *Atlantis* and Her First Oceanographic Institution," in Sears and Merriman, *Oceanography: The Past*, 49-56; See also Schlee, *On Almost Any Wind: The Saga of the Oceanographic Research Vessel* Atlantis (Ithaca: Cornell University Press, 1978).

experts as well. The next chapter will discuss the Committee on Oceanography's report, which contains the committee's discussions and the solution to the problems of American oceanography they finally found. The committee studied the state of oceanographic research and education in Europe and in America, and arrived at the idea that founding a new institution would be the solution to the many problems of oceanography on the east coast of the United States.

CHAPTER 5
Building Oceanography on the American East Coast II: The Report of the National Academy of Sciences Committee on Oceanography

The discussion on the state of oceanography in the United States began privately when Wickliffe Rose and Frank Lillie met in Chicago in 1924. With the forming of the Committee on Oceanography of the National Academy of Sciences in 1927, the discussion became official and continued on a new level. This chapter will summarize and analyze the committee's report submitted to the Academy in 1929, which contained the committee members' final understanding of the problems of American oceanography and the best remedy they proposed.[1] It will show how American leaders of ocean sciences saw the state of oceanography at that time and what they wanted the future of that science to look like.

1. The Report of the Committee on Oceanography

Henry Bigelow, as secretary of the Committee on Oceanography, put his best efforts into the writing of the committee's final report regarding the state of

[1] Henry B. Bigelow, "Report on the Scope, Problems and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies," Report of the Committee on Oceanography of the National Academy of Sciences, Frank R. Lillie, Chairman. 1929. For the background of the Committee on Oceanography, see Frank R. Lillie, *The Woods Hole Marine Biological Laboratory* (Chicago: University of Chicago Press, 1944), 177-191; Harold L. Burstyn, "Reviving American Oceanography: Frank Lillie, Wickliffe Rose, and the Founding of the Woods Hole Oceanographic Institution," in Mary Sears and Daniel Merriman, eds., *Oceanography: The Past* (New York: Springer-Verlag, 1980), 57-66; and Roger Revelle, "The Oceanographic and How It Grew," in Sears and Merriman, *Oceanography: The Past*, 10-24.

oceanography in the United States and elsewhere and the ways to improve the situation on the American east coast. He conceived it as a means to present not only the discussions and decisions of the committee as a whole but also his own ideas and vision for American oceanography. The report can justifiably be called the best non-technical monograph on oceanography written in the first half of the twentieth century. Its value was readily appreciated by those who read the manuscript of the report, and it was soon published as a book with minor revisions.[2] As a matter of fact, this masterpiece could not be written by anyone else but Bigelow, an experienced researcher and visionary of oceanography. Having carried on his own research project at the Gulf of Maine for more than a decade, he knew better than anybody else in the United States about the state of the science of oceanography at that time, available resources and problems in pursuing oceanographic work on the east coast, ways to remove the existing obstacles, and the direction which the proposed reform in American oceanography had to take.

"Report on the Scope, Problems and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies" was submitted to the National Academy of Sciences on November 18, 1929 and became a blueprint for the establishment of the Woods Hole Oceanographic Institution which happened immediately after the submission of the report. It took only about a year to open the new institution, and this is no doubt a surprisingly short time for such a large-scale task. It was possible first of all because of the strong support of the Rockefeller Foundation, which resulted from Wickliffe Rose's wholehearted commitment to the project. Facing his impending retirement, he transferred the project from the General Education Board to the Rockefeller Foundation and had Max Mason, who was director of the Division of Natural Sciences and then president of the Foundation, look after it.[3] He considered the founding of an oceanographic institution the last large-scale project in his career. It was also important that there had been enough discussion and agreement about the steps that needed to be taken. Years of fertile discussion for the direction of American oceanography enabled the committee to present a detailed master plan, which was fully represented in Bigelow's report. In this respect, it is necessary to take a close look at the contents of the Report, which provides a useful

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[2] Henry B. Bigelow, *Oceanography: Its Scope, Problems, and Economic Importance* (Boston: Houghton Mifflin, 1931).
[3] Lillie, *The Woods Hole Marine Biological Laboratory,* 180.

window through which American oceanography in the late 1920's can be seen.

The Report comprises eight chapters which deal with "the scope, problems and economic importance of oceanography," "the present situation in America," "the handicaps to development," and "suggested remedies" as the title clearly tells. An overview of the science of oceanography and its economic value are discussed in chapters 1 and 2,[4] respectively; the state of oceanography practiced in America and Europe is discussed in chapters 3, 4, and 5; problems, the committee's suggestion for the remedy to the problems, and considerations on the shape and site of the proposed east-coast oceanographic institution are dealt with in chapters 6, 7, and 8; finally, the Report ends with "Recommendations to accompany the Report of the Committee on Oceanography of the National Academy of Sciences as submitted to the Academy November 18, 1929."

2. "Scope and Present Problems of Oceanography": The Complex Interconnected System

In the first chapter, Bigelow defines and categorizes the divisions of oceanographic research. For each subdivision of oceanography Bigelow tells of the most important and up-to-date topics of research, and goes on in detail to describe the achievements and problems of the oceanography of his time. He begins the Report with the remark that "Oceanography has been aptly defined as the study of the world below the surface of the sea: it should include the contact zone between sea and atmosphere."[5] Bigelow goes on to explain that oceanography consists of its sub-disciplines, a scheme closely resembling that of Vaughan, and others.[6] Three to six fields had often been

[4] The first two chapters later became the monograph *Oceanography: Its Scope, Problems, and Economic Importance*.
[5] Bigelow, "Report," 1.
[6] For Vaughan's ideas on the science of oceanography, see T. Wayland Vaughan, "The Scripps Institution—Its Present Work in Oceanography and Suggestions for Its Future Development" (1924), Records of the SIO Office of the Director (Vaughan), 1924-1936, Scripps Institution of Oceanography Archives, University of California, San Diego.

mentioned as subdivision of oceanography: physical oceanography, chemical oceanography (which was sometimes included in physical oceanography), marine biology, marine geology, meteorological aspects of oceanography, and ocean engineering. In this Report, Bigelow does not mention ocean engineering as a subfield of oceanography, and deals very briefly with marine meteorology, filling the section entirely with a quotation from a meteorologist.[7] Therefore, the first chapter of the Report mostly concentrates on summarizing and explaining the important topics and contemporary researches of “Submarine geology,” “physics of the ocean,” “chemical aspects of oceanography,” and “life in the sea.”

Throughout the chapter, the most important point that Bigelow makes is that the natural phenomena of the oceans are complex and no one subfield alone can satisfactorily explain most of the oceanic features. He writes:

> [Oceanography] is thus widely inclusive, combining Geophysics, Geochemistry and Biology. Inclusiveness is, of course, characteristic of any “young” science, and modern Oceanography is in its youth. But in this case it is not so much youth that is responsible for the fact that these several subsciences are still grouped together, but rather the realization that the Physics and Chemistry and Biology of the sea water are not only important *per se*, but that in most of the basic problems of the sea all three of these subdivisions have a part. And with every advance in our knowledge of the sea making this interdependence more and more apparent, it is not likely that we shall soon see any general abandonment of this concept of Oceanography as a mother science, the branches of which, though necessarily attacked by different disciplines, are intertwined too closely to be torn apart.[8]

The interdependence among the subfields of oceanography makes it indispensable that a specialist in one know some of all the others. This point partly gives an answer to Bigelow’s strong interest in physical oceanography as shown in his Gulf of Maine

[7] Moreover, the pagination of the part on meteorology, 66a, 66b, and 66c, shows that the section was probably a later inclusion.
[8] Bigelow, “Report,” 1.

studies.

It is difficult to understand why Bigelow, a biologist by education and training, devoted much of his oceanographic work to the physical aspects of the sea even though he admittedly lacked mathematical skills. Apparently, he must have been impressed by the work being done by physical oceanographers of the northern European countries, especially in the area of oceanic dynamics. Besides that, the Report also reveals important pieces of his thought. “We also have,” writes Bigelow, “other impelling reasons for making Ocean Physics a primary subject in the fact that, as one contributor writes, “virtually all kinds of studies of the sea are crying for more information on physical conditions within it.”” Not only for marine biologists but also for experts in other areas of oceanography, knowledge of the physical properties of the sea was badly needed, and Bigelow as an oceanic biologist must have felt it himself which resulted in his awareness of the importance of physical oceanography. In reality, however, this field was not so well developed as to support those related marine sciences. Why? Bigelow diagnoses that, ironically, the very necessity of physical oceanography for other fields hindered its progress.

> The temperature of the water, its chemistry, and the mechanical manifestations of oceanic circulation, not only govern the whole economy of life in the ocean, but also produce important geological results, and go far to govern climates on land, past as well as present. With these last incentives, it was natural that a tendency developed to treat physical and especially dynamic Oceanography as a subject auxiliary to oceanic biology or to geology. The fact that oceanographic work on the two sides of the Atlantic has long drawn its chief impetus from the economic pressure of fisheries problems, has been largely responsible for this relegation of ocean physics *per se*, to a secondary position. This tendency, however, has seriously retarded the advance, not only of our knowledge of the physics of the ocean *per se*, but even of the very branches that it was hoped to further; for it may be taken as axiomatic that only when any scientific field is considered as a primary object, worthy of cultivation for its own sake, can satisfactory advance

therein be expected.[9]

Bigelow felt that it was imperative to expedite the development of physical oceanography, which could be achieved only by freeing it from the influences of other fields. And that was, perhaps, the reason why he treated physical study separately in his Gulf of Maine project.

Even though Bigelow emphasizes the urgent need for physical oceanography to develop on its own, it by no means implies that biologic, or geologic, interests must never enter the study of physical oceanography. The usefulness and indispensability of physical knowledge of the sea in tackling other branches of oceanography are emphasized here and there. He begins, for example, the section on circulation with such a remark: "It is as essential for the oceanographer to understand the circulatory movements of the water, if he is to comprehend any of the events that take place in the sea, whether biologic or geophysical, as it is for the meteorologist to understand the systems of winds on land."[10] For Bigelow, each subfield of oceanography, and physical oceanography in particular, had to be developed independently, yet always in the service to the other areas of oceanography, providing necessary knowledge and information.

Physical oceanography's development as a service science within the whole realm of marine sciences partly had to do with the relationship it had with general physics, as compared with marine geology or biology. In the early decades of the twentieth century, marine biology was at the forefront of general biology, being considered as a key to important biological problems of the time such as evolution, heredity, and development.[11] In geology, too, marine phenomena were considered to be a very important part of contemporary geology as a whole, with the awareness that land and marine geology were closely connected.[12] In the physics and chemistry of the sea the situation was quite different. If physics and chemistry of the sea were often

[9] Ibid., 17.
[10] Ibid., 24.
[11] Ronald Rainger, Keith R. Benson, and Jane Maienschein, eds., *The American Development of Biology* (Philadelphia: University of Pennsylvania Press, 1988); Keith R. Benson, Jane Maienschein, and Ronald Rainger, eds., *The Expansion of American Biology* (New Brunswick: Rutgers University Press, 1991).
[12] For example, the topic of coral reef formation interested many geologists. Alistair W. Sponsel, "Coral Reef Formation and the Sciences of Earth, Life, and Sea. c.1770-1952," Ph.D. Dissertation, Princeton University, 2009.

considered, implicitly and explicitly, service sciences to other oceanographic branches, it may have been because marine biologists and geologists were more interested in, and in need for, them than other physical scientists working on issues not related to the sea.

> The studies of the Physical-Chemistry of sea water that are now in progress, like those of its physics, chiefly aim at enlarging our factual knowledge of regional variations and our understanding of events that take place in the cycle of matter there, rather than at clarifying the nature of chemical processes as such. They thus bear to the science of physical-chemistry as a whole a relationship more subsidiary than do oceanic biology or physiology to current attempts to fathom the riddle of life.[13]

Bigelow, on the other hand, believed that physical and chemical oceanography formed the more basic parts of the ocean science. If these sciences were not developed sufficiently, researches in other branches, particularly oceanic biology, would necessarily be greatly hampered.

The complexity of the natural phenomena in the sea called for a unique style of doing science, often quite different from other areas of natural sciences. An expert in one realm of oceanography not only had to have some knowledge of the others, but also had to work in cooperation with other specialists.[14] Bigelow writes:

> This, then, is the real goal of the marine biologist—to understand the cycle of matter and of energy in the ocean. But he is helpless without the assistance of the chemist, or the physicist, of the bacteriologist, of the geologist.[15]

Elsewhere, he also writes:

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[13] Bigelow, “Report,” 38.
[14] This point was emphasized again in Bigelow, “A Developing View-Point in Oceanography,” *Science*, 71 (1930): 84-89.
[15] Bigelow, “Report,” 66.

> The necessity for uniting several disciplines in this case illustrates how broad a view we must take of bio-physical and bio-chemical problems as a whole in the ocean.[16]

It was apparent that during the cooperative research on complicated oceanic problems, ocean scientists had to have a "broad view" on marine phenomena. This idea naturally led Bigelow to the problem of education and training of oceanographers. How could scientists be trained to have a broad view needed for oceanographers? Bigelow's answer is that "This cannot very well be done unless students are brought into direct contact with marine conditions during their formative years."[17] Only by going to the sea and directly experiencing the oceanographic research there could this purpose be properly achieved. The idea of the unique complexity of oceanography also led Bigelow to conclude that seaside laboratories devoted to oceanographic work were important.

> But for him to make the most of these opportunities (and especially in America) has heretofore been difficult, chiefly because the problems are technically too elaborate to be successfully attacked as isolated projects during the brief and discontinuous periods of study to which most university professors must limit their researches. As headquarters for such work a shore laboratory is needed, equipped for first-class investigations of the chemical and physiological problems that will arise from preliminary and exploratory studies made on shipboard. A further obstacle is the need in most of such problems for continuous cooperation between students specializing in different fields.[18]

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[16] Ibid., 63.
[17] Ibid., 51.
[18] Ibid., 55-56.

3. “Economic Value of Oceanographic Investigations”

Bigelow discusses in the second chapter the practical usefulness of oceanography in several areas: sea fisheries, navigation, harbor construction, laying of submarine cables, and weather forecast. He mentions all these areas of economic human activities with not only actual and direct but also potential contributions oceanography could offer in mind. But by far the two most important areas that Bigelow emphasizes are fisheries and navigation where, he thought, oceanographers’ assistance could immediately be felt were they given enough resources to pursue their research and the opportunities to apply their findings in those realms.

The first thing Bigelow does in discussing the sea fisheries is to describe the basic problem, which is “to make the greatest possible use of the food resources of the sea that is compatible (a) with avoiding the danger of overfishing; (b) with safeguarding the industry against the disastrous effects of unpreventable fluctuations in the available supply of fish.”[19] Both of these aims could best be achieved by help from oceanographic studies, for he continues:

> Although the problems involved in these two cases are fundamentally distinct, in each case the solution can only come from investigations of the life histories of the fishes involved, and of their reactions to their environment, animate and inanimate, combined with statistical study of the commercial catch. In other words, the technique of oceanic biology must be employed, whether the aim be protection or prediction.[20]

Fisheries studies had not often been carried out in the direction of “oceanic biology” until that time unfortunately, mainly because of the limitations inherent in the governmental bureaus of fisheries that were responsible for the fisheries researches in most countries, including the United States, Canada, and the northern European countries.

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19 Ibid., 73.
20 Ibid.

In fact, sea fisheries was an area where scientific research was very active at both regional and international levels, as was testified by the work of the International Council for the Exploration of the Sea. In America, the governments of Canada and the United States also had been cooperating on some important fishery issues, and Bigelow especially mentions the treaty between the two countries on the "regulation of halibut fishery off the northwest coast of North America."[21] The fisheries services of those countries were actively pursuing scientific studies in addition to their regulation programs. The kind of investigation that received most of their efforts was attacking the problems of fisheries with statistical methods, which Bigelow calls "vital statistics."[22] The most pressing issue for the fishery policy was to understand the state of the populations of major food fish stocks, which allowed prediction of the amount of catches in the next few years. And the fishery bureaus "attempt[ed] to interpret the trends that the statistics of the catches disclose[d], whether up, down or stationary." But Bigelow points out that without a sound scientific basis as to the life histories of the fishes and their physical-chemical environment, the analysis of statistics and the predictions based on it would be unreliable. With the statistical approach, which rendered no hint of the state of affairs under the sea, it was impossible to understand "the interrelationships of the very complex chain of events in the sea." Even though oceanographic investigations "seemed at first sight utterly remote from any practical application," they had to be undertaken in order for the fishery studies to be placed on the right track. Only on the basis of the knowledge of oceanic biology could the methods of vital statistics become meaningful.[23]

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[21] Ibid., 80. The Convention for the Preservation of the Halibut Fishery of the Northern Pacific Ocean was signed on March 2, 1923 by the United States and Canada. It had a provision for a three-month closed season during the winter. The convention also established the International Pacific Halibut Commission (IPHC) for the joint management of the Pacific halibut fishery. The U.S. and Canada each appointed two commissioners for the IPHC. The convention was important in Canadian history since it was the first foreign treaty signed by Canada alone, independent of Britain. Committee on the Applications of Ecological Theory to Environmental Problems, National Research Council, *Ecological Knowledge and Environmental Problem-Solving: Concepts and Case Studies* (Washington, D.C.: National Academy Press, 1986), 137-150.

[22] Bigelow, "Report," 74.

[23] It was only in the 1970s that oceanography came to be applied to fisheries successfully. Until that time, oceanography could not yield meaningful results for the industry, and the leaders of the fishery industry seldom thought of the science necessary for their industry. Since the

The very fact that oceanographic studies seemed so "remote from practical application" and that they had to be supported "over a period long enough for the study to reach a productive stage" prevented congresses in each country from approving the funding of that line of work at governmental fishery services.[24] How, then, could the situation be reversed in the United States? How could the trend of "building the structure from the roof downward" be stopped? Bigelow's answer lay in a new oceanographic institution not directly affiliated with the government that could play the initiative role in the study of oceanic biology. Such an institution would be able to conduct periodic, long-term investigations of the ecology of major food fishes and their environments without being hampered by the kind of limitations that the government agencies had been destined to endure. Bigelow writes:

> It is idle to suppose that oceanwide expeditions, undertaken at long intervals, will be of much value in advancing investigations of this sort. What is needed is intensive study either of regions, of individual species, or of particular fisheries, as the case may be. These must be so long continued (because covering so wide a field and concerned with the natural economy of generation after generation), and so intensive (because of the nature of the problems involved), that individual investigators can make but slow progress. In no field, in fact, are joint efforts, and the services of cooperative agencies more needed in American Oceanography, than in fisheries Biology. The work of the Federal Fisheries Services of North America would benefit greatly by the assistance of any institution that could initiate and encourage research in the basic fields of oceanic biology, to which the governmental agencies cannot give due attention because of legislative allocation of their funds to objects that may seem more directly

beginning of the efforts on the part of ocean scientists to solve the fisheries problems, it took about a hundred years for oceanography to actually contribute to the fisheries production. See Michael L. Weber, *From Abundance to Scarcity: A History of U.S. Marine Fisheries Policy* (Washington, D.C.: Island Press, 2002); and Arthur F. McEvoy, *The Fisherman's Problem: Ecology and Law in the California Fisheries, 1850-1980* (New York: Cambridge University Press, 1986).

[24] Bigelow, "Report," 74.

profitable from the economic standpoint.[25]

The discussion on the role of oceanography in promoting the fishery industry was important for the Committee on Oceanography as it justified the turn from fisheries studies to general oceanography that took place earlier in the series of conferences among Rose, Lillie, and others.[26]

Another area of human activity where the usefulness of oceanographic knowledge could directly be felt, to a lesser degree than fisheries, was navigation. "In a general way," Bigelow remarks, "the sea, as a high road for commerce, now serves man's purposes adequately."[27] It was probably because accumulated information as to the natural phenomena of the oceans affecting the safety and effectiveness of navigation had been extensive enough and, at the same time, because navigation technology had sufficiently progressed. But as the tragic accident of the *Titanic* in 1912 vividly showed, detailed knowledge of physical oceanography in regions throughout the oceans was still lacking and greatly desired. In this part, Bigelow mentions two factors in some detail: currents and soundings.

Slow freight ships were more affected by the ocean currents than "fast passenger liners which [could] often disregard the current." But most of the world's maritime commerce was carried by these freighters, and thus better understanding of the global current system had a tremendous economic value. Perhaps the time saved by a single passage might not have been big, as Bigelow points out, yet "either small savings, or small losses, when cumulative, reach staggering proportions in the course of years." Extended time meant more fuel consumed, and if commercial vessels could save as much fuel as they could by drifting with ocean currents it would contribute much to the

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[25] Ibid., 80. Bigelow's own research on the Gulf of Maine, supported by the U.S. Bureau of Fisheries, was the best example of such joint scientific efforts in fisheries biology. Jeffrey P. Brosco, "Henry Bryant Bigelow, the U.S. Bureau of Fisheries, and Intensive Area Study," *Social Studies of Science*, 19 (1989): 239-264

[26] Originally, Rose intended to support agricultural studies and later fisheries studies since he had more practical aims. Burstyn, "Reviving American Oceanography," 57-66.

[27] Bigelow, "Report," 81. It should be noted that the scientific interest in the oceans began in the United States in the domain of navigation. A. Hunter Dupree, *Science in the Federal Government: A History of Policies and Activities to 1940* (Cambridge, Mass.: The Belknap Press of Harvard University Press, 1957), 29-56.

commercial profits.[28] Impact of currents on navigation had long been known, in fact, especially in the northern Atlantic where the Gulf Stream exerted so much influence on sailing ships. Thus, much work had been done to understand the global oceanic current patterns and the accumulated information was extensive enough to render a big picture of the global current system. But "In parts of South Atlantic, Indian and Pacific Oceans," Bigelow contends, "we still lack sufficiently detailed knowledge of velocities and precise directions, of the effects on these of varying winds, and of seasonal variations, to allow intelligent planning of routes for slow ships…."[29] There was still much more to be desired in the realm of the study of ocean currents.

In the domain of marine researches for navigation, here, too, governmental agencies were the leading forces, not only in the United States but also in most of the major seafaring nations. Since the time of Matthew Fontaine Maury, the Hydrographic Services of many nations had been actively involved in gathering current information from ships' logbooks and other sources available in order to improve the yearly and monthly current charts they published.[30] Another organization involved in the study of ocean currents was the International Ice Patrol. It was not only the ships whose courses were influenced by currents; icebergs from the polar regions also drifted along the ocean currents. Monitoring and predicting the course of polar icebergs, which was very important for the safety of ships, were the main mission of the Ice Patrol. Studying ocean current system, therefore, had an important place among the duties of this organization.[31]

What was needed, according to Bigelow, was a scientific understanding of the causes and effects of the physical factors that govern the phenomena of oceanic currents, for which the mere accumulation of the logbook information could hardly do much. Instead, a systematic and wide-range work of data collecting and analyzing had to be done on a long-term basis, utilizing the method of oceanic dynamics developed by the Scandinavian geophysicists. Such a large-scale work could not be carried out by a single

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[28] Bigelow, "Report," 81.
[29] Ibid.
[30] Ibid., 83.
[31] Bigelow had been involved with the International Ice Patrol as special consultant to the Commandant of the Coast Guard. He educated its officers at the Museum of Comparative Zoology. Alfred C. Redfield, "Henry Bryant Bigelow," *National Academy of Sciences Biographical Memoirs,* Vol. 48 (1976): 50-80. See especially pp. 57-58.

competent institution but had to be a cooperative venture among many such institutions at an international scale. Were the governmental agencies such as the hydrographic services suitable for this mission? No.

> Work of this sort, however, can hardly be attempted on a large scale by any governmental establishment, because the difficulty of demonstrating an immediate economic result makes legislative support difficult to win. And while the development of methods of attack, etc., often draws inspiration from one or another isolated center or individual, successful application to the oceans demands cooperation between many institutions, because the field is oceanwide. Observations must also be carried on for many years to trace the long-time fluctuations that are already known to occur. Some center of inspiration and coordination is sorely needed to encourage work of this sort in America.[32]

Again, Bigelow takes the discourse to the conclusion that a new oceanographic institution is needed.

Sounding, or underwater topography, was another area of oceanography that was also important for navigation. Utilizing sounding in navigating at relatively shallow waters near shore was a well known technique particularly in a foggy weather. With the newly developed apparatus of sonic sounding, navigation was expected to be greatly facilitated when aided by improved charts showing accurate ocean depths. To this oceanographers could contribute.[33]

Another area that received a lengthy discussion was long-term weather forecasting which, Bigelow thought, had been showing some positive prospect considering the developments during the previous few years. The idea of predicting the weather according to the physical conditions of the sea was not new since it had long

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[32] Bigelow, "Report," 83.

[33] Ibid., 84-85. For the history of sonar development, see Willem D. Hackmann, *Seek and Strike: Sonar, Anti-Submarine Warfare, and the Royal Navy, 1914-54* (London: Her Majesty's Stationery Office, 1984); Hackmann, "Sonar Research and Naval Warfare 1914-1954: A Case Study of a Twentieth-Century Establishment Science," *Historical Studies in the Physical and Biological Sciences*, 16 (1986): 83-110; and Harry von Kroge, *Gema: Birthplace of German Radar and Sonar* (Philadelphia, PA: Institute of Physics Publishing, 2000).

been believed that a close relationship did exist between the atmosphere and the upper layer of the ocean. Scientists knew that the ocean temperature information was not useful at all for everyday weather forecasting, but it was inferred that it would offer reliable ways to make long-term predictions, at least several months in advance, if appropriate methods were developed. If that was really possible, it would surely mean a tremendous benefit for some industries, such as "the clothing trades, power and transportation companies, and certain branches of agriculture."[34]

The first step for the proposed weather forecast was collecting as extensive data as possible on the sea-surface temperature in a wide area on a regular basis. There were already several available sources of such temperature data and, thus, the basic information was plentiful. The prospect for this stage of work was overall "encouraging" especially for the north Atlantic. Ships, mostly trans-Atlantic steamers, had apparatus such as continuous seawater thermographs installed and were sending in piles of useful data. The Hydrographic Office had its sources for such data, and the Weather Bureau also was developing a system of data collecting. Notwithstanding the fact that more data were desirable in other parts of the oceans, particularly from outside of the regular steamship tracks, for the northeastern United States, enough information as to the sea surface temperature was already in hand.[35]

It was more difficult with the next step, namely analyzing the huge amount of data gathered from the sea. The acquired raw data could not be used directly in relating the temperature information with atmospheric conditions but rather had to go through tedious procedures of processing and analyzing by experienced workers in order to produce the final information useful for predicting weather. "The most serious obstacle to the advance of knowledge as to the general relationship between sea temperatures on one hand, and atmospheric temperatures and pressures on the other" was, Bigelow writes, "the inability of any existing agency to undertake analysis of the enormous mass of data that has already been amassed, and that will continue to accumulate at an appalling rate if continuous observations are taken on many ships running along as many different routes."[36] The immense amount of the surface temperature data collected at the sea far exceeded the capacity of those institutions and agencies involved at that time in such a

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[34] Bigelow, "Report," 88.
[35] Ibid., 92.
[36] Ibid.

task, and to meet the challenge additional funds and personnel had to be supplied. However, "the impossibility (if we are to be intellectually honest) of promising direct economical benefits therefrom" made it hardly possible for governmental agencies to get an approval from the Congress for such additional resources.[37]

To Bigelow, the situation of the project of long-term weather forecast, based on the changes in the sea surface temperature, seemed to point to the necessity of an oceanographic institution, again. He writes that the want of immediate economic promise and the difficulty the federal agencies were having "[made] research institutions particularly appropriate centers for certain aspects of such work, in cooperation with the governmental weather bureaux."[38] Bigelow, in fact, had a good reason to be confident of the advantage of research institutions in the task of leading the oceanographic research aimed at weather forecast compared with governmental organizations. He had always been in close contact with the Scripps Institution in California and was well informed of the scientific work being done there.[39] George McEwen's project of long-term weather forecast had been one of the major research programs of the Scripps Institution of Oceanography since the time of the founding director William Ritter. T. Wayland Vaughan, director at that time and a member of the Committee on Oceanography, also found this project very important and promising, and he had been encouraging the physical oceanographer to pursue the project further. Scripps Institution's seemingly successful achievements in the previous twelve years seemed to Bigelow to firmly support his claim of superiority of non-governmental institutions as a leading force in the research in that direction. He cheerfully writes that "The very encouraging progress that has been made in the experiment now being carried out by the Scripps Institution corroborates this view."[40]

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[37] Ibid., 93.

[38] Ibid.

[39] Bigelow had personal ties to Charles Kofoid, who joined Agassiz's expedition in 1904, Ellis Michael, T. Wayland Vaughan, and others at Scripps. See for example, Letters from Kofoid to Bigelow on January 20, 1910 and on January 24, 1911; Letters from Ellis L. Michael to Bigelow on February 24, 1913 and on March 12, 1913, *Henry Bryant Bigelow Papers*, Harvard University Archives.

[40] Bigelow, "Report," 93. For McEwen's work at the Scripps Institution, see Eric L. Mills, "Useful in Many Capacities: An Early Career in American Physical Oceanography," *Historical Studies in the Physical and Biological Sciences*, 20 (1990): 265-311; and Mills, "The Oceanography of the Pacific: George F. McEwen, H. U. Sverdrup and the Origin of Physical

It is obvious that not all the information and ideas in this chapter on the economic importance of oceanography came from Bigelow alone, nor could he have done all the researches needed for the writing of it. Although this report does not have notes or references on bibliography, Bigelow mentions, here and there, some sources he used and consulted. For instance, he quotes a passage from Sir Napier Shaw's book *Forecasting Weather* that pointed out the difficulty in making simple relations between sea temperature and atmospheric conditions.[41] Bigelow also mentions D. K. Tressler's book *Marine Products of Commerce* in the section on "Utilization of Other marine Products."[42] In addition to mentioning names of experts and monographs, Bigelow continues to refer to "the Conference on Oceanography at the U.S. Navy Department in 1924." For example, a remark by a representative of the U.S. Coast Guard on "the importance of a study of the expansions and contractions of polar ice through Bering Straits, to safeguard the voyages of the whalers to the Arctic coasts of Alaska and Canada" is mentioned; General Edgar Jadwin's opinion on the need for a good understanding of the direction of currents in planning harbor entrances on sandy coasts is noted; and Colonel C. A. Seons' emphasis on the importance of knowing bottom topography in Submarine cable laying is cited.[43] This conference, where Bigelow himself was probably present, apparently exerted an immense influence on his understanding of various issues related with ocean sciences. The fact that such a conference was held in 1924 shows the great interest oceanography was receiving in the United States from scientists, engineers, governmental agencies, and the Navy.

The issue of economic value of oceanographic researches formed a crucial part of the Report as well as the committee's discussions because it was the basis of the argument that oceanography was useful for the welfare of the nation and the demand that

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Oceanography on the West Coast of North America," *Annals of Science*, 48(1991): 241-266.

[41] Bigelow, "Report," 91. Sir Napier Shaw, *Forecasting Weather*, 2nd edition (London: Constable & Co., 1923). Meteorology was the one field for which Bigelow seemed to rely most on other experts' specialist opinions. In the first chapter of the "Report," he filled the section on marine meteorology solely with the statement of C. F. Brooks. Bigelow, "Report," 66a-66c.

[42] Bigelow, "Report," 80. Donald K. Tressler, *Marine Products of Commerce: Their Acquisition, Handling, Biological aspects, and the Science and Technology of Their Preparation and Preservation* (New York: The Chemical Catalog Company, Inc., 1923).

[43] Bigelow, "Report," 83, 85, and 86. For the federal Interagency Conference on Oceanography (ICO), see Gary E. Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment* (College Station: Texas A&M University Press, 2001), 21-52.

it needed to be supported by the Rockefeller Foundation. At a time when the practical importance of ‘pure’ science such as oceanography was doubted, a full discourse on its economic value was indispensable.

4. The State of Oceanography in the United States and Abroad

In the nineteenth century, according to Bigelow, the United States retained the position of one of the few leading countries in the realm of marine sciences. Soon after the turn of the twentieth century, however, “there followed in America a period of stagnation.”

> It is, in fact, hardly an exaggeration to describe Oceanography in America during the first years of the present century as “dead,” with the old ways no longer yielding advances commensurate with the effort. This period of stagnation, however, was short, and the awakening that followed must fairly be credited to the example of the International Committee for the Exploration of the Sea, in North European waters.[44]

The early-twentieth-century fall of American oceanography, diagnoses Bigelow, resulted from the fast development of the science of oceanography and the failure of American oceanographers to keep up with the transforming trend. Nineteenth-century oceanographic work consisted mostly of large-scale expeditions, often funded by the state, and those expeditions covered large areas of the oceans during a period that often lasted several years. This method was appropriate at a time when virtually nothing was known about even the general features of the oceans with the exception of some coastal regions which had long been the domain of human activities. With the accumulation of the various data from the nineteenth-century expeditions, however, oceanographers were now able to grasp the big picture of the ocean systems, and what they needed more at

[44] Bigelow, “Report,” 94.

this stage was detailed information of specific areas, or aspects of the sea. "[T]he day of pioneering passed," writes Bigelow, "and . . . continued exploration in these preliminary lines proved more corroborative than novel."[45]

> Oceanographic exploration, whether its aim be biologic or physical, has by natural process of evolution developed along two lines. It may be carried on by great deep-sea exploring expeditions, oceanwide in scope, but comparatively short in duration; and sent out as more or less isolated events in the general progress of science. As the need of more intensive knowledge developed, continuous or at least periodic study of areas within a few hundred miles of the home station have proved more and more fertile, such as can be carried out on a small vessel at small expense. It is this procedure that has contributed most to the modern advance of Oceanic Biology. The deep-sea expedition was the method of early days of the science. As just remarked, the day is passing for expeditions of this sort, except in the realms of physical and chemical Oceanography.[46]

American oceanography, which continued to cling to the large-expedition style of oceanography, lagged behind in the early twentieth century just because it did not react promptly to the demand of the new oceanography. Marine scientists in the United States failed to adapt themselves quickly to the new method of ocean research which became essential for further progress into the next phase.

4.1 European Oceanography

In contrast to the situation in the United States, "Nothing of this sort happened in Europe," and there had been no period of stagnation in ocean sciences comparable to the "dead" American oceanography.[47] There developed in Europe a new line of oceanic

[45] Ibid.
[46] Ibid., 95.
[47] Ibid., 135.

research that Bigelow called "intensive study." The origin of the new oceanography was closely linked to the problems of fisheries, and was pursued in order to explain and predict the annual fluctuations of fish harvests in the northern European countries. Bigelow writes:

> In Europe, however, synchronous with this American decline, there had arisen new schools centering their attention not so much on regional surveys of the oceans as on the biologic economy of its inhabitants as governed by their physical and chemical environment. This change of viewpoint, from the descriptive to a conscious attempt to interpret oceanic phenomena in terms of its organic inhabitants, marks the beginning of the modern science of Oceanic Biology, and it is interesting that the real incentive came, in this case, from the demands of declining fisheries for betterment, i.e. from economic necessity.[48]

There was a belief that science could help solve the problem of fluctuating fisheries yield from year to year, which often caused a disaster to the economy of the Scandinavian nations as the national economy of those countries depended heavily on the fishery industry. The scientific study of the ecology of the fishes was actively pursued, and the Scandinavian scientists soon came to understand that the physical properties of the ocean, such as temperature, salinity, and currents, were important factors governing the life histories of the major food fishes. The intensive area study method was developed in order to satisfy the needs of the fisheries studies, supported by the ocean dynamics newly developed in Scandinavia.[49]

A notable feature of the European oceanography, or the study of the sea, was the numerous scientific institutions built actively in many countries throughout the European continent. "[A] widely disseminated interest in the sea" was translated "into the development of a large number of institutions," which were "designed to encourage researches in a wide variety of fields, biological, physical, and chemical . . . ."[50] A great diversity existed among the European institutions which were devoted to one or another

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[48] Ibid., 94.
[49] Ibid., 94.
[50] Ibid., 137.

aspect of oceanography. Many of them were devoted to the fishery studies, while still more were marine biological laboratories.[51] There were some institutions, mostly governmental, that concentrated their efforts on hydrography—and in some cases with combined interests in marine biology. In many cases, the institutions were devoted not just to one branch of ocean science but rather to several interconnected fields, acknowledging the complex relationship among the oceanic phenomena. The European institutions also varied as to whether they were private, governmental, or subordinate to universities. Some were founded and run by individual, or a group of, private scientists while others belonged to state universities if not directly sponsored by governments.[52] To Bigelow, the crucial factor that contributed to the productivity of the marine institutions in Europe was the fact that they were "in many cases actually endowed with the material means, and with the personnel requisite for that purpose," which their American counterparts mostly lacked.[53] This was much more important than the mere number of institutions devoted to marine sciences.

The second, and perhaps more important, key to the prospering of European oceanography was the existence of international coordinating agencies. As European scientists continued their study of "oceanic biology" and physico-chemical oceanography, they soon felt that successful oceanographic work would be far beyond the ability and boundary of a single nation, not to mention a single scientist. The sea has no natural boundary and, thus, the movements of currents and fishes are not confined to limited areas of the sea. In the nineteenth century, large-scale oceanographic expeditions were often carried out competitively for the purpose of enhancing national prestige and pride. With the shift in emphasis, and as the dominating methodology changed, however, what ocean research now required was international cooperation rather than national competition. How such international cooperation in oceanography could actually be achieved was a difficult problem. There existed a tradition in oceanography to distribute specimens gathered during major oceanic expeditions to prominent scientists according

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[51] Bigelow reported that "A list recently published names upwards of 70 of [marine institutions] in European countries." Bigelow, "Report," 136. For an earlier account of the European marine stations, see Charles A. Kofoid, *The Biological Stations of Europe* (Washington, D.C.: Government Printing Office, 1920).
[52] Bigelow, "Report," 135-137.
[53] Ibid., 137.

to their expertise and regardless of their nationality.[54] The specialists would, then, study the group of animals or plants allotted to them and write a report for the expedition. The international cooperative scheme now being considered at the end of the nineteenth century among northern European oceanographers was a wholly different one from that tradition. What they envisioned was a cooperative venture at the level of governments, with the whole community of ocean scientists and institutions of each country participating, for which there had not been any precedent. It was very opportune for oceanography because "just when the need for general coordination in this science became most pressing," writes Bigelow, "an impelling stimulus in that direction was provided by growing fears of depletion of the sea fisheries, coupled with growing appreciation of the obvious truth that it would be idle to seek remedial measures unless all the nations whose fisheries drew from the threatened areas would unite in joint examination of the existing status."[55]

In the Report, Bigelow mainly mentions three European coordinating agencies of oceanography: the International Council for the Exploration of the Sea, the International Council for the Exploration of the Mediterranean Sea, and the International Hydrographic Bureau. Of the three, the ICES was by far the most influential, and most important for the development of oceanography. For, in the case of the ICEMS, the aim was merely "the exchange of information as to the work in progress by each and the encouragement of coordination, generally, between the different national services that actually have scientific investigations in progress in the Mediterranean," and the actual coordinating function was rather weak.[56] In contrast, an "outstanding characteristic of . . . [this] International and Official Agency [ICES]" was that it was endowed "with executive power to insure coordination of scientific effort between the fisheries Bureaux of the various European countries, [which had] no direct parallel elsewhere."[57]

> This control has resulted from the fact that throughout its existence the Council has been entrusted with the duty of coordinating the scientific

[54] The collection of the *Challenger* Expedition is a good example. Susan Schlee, *The Edge of an Unfamiliar World: A History of Oceanography* (New York: E.P. Dutton, 1973), 125-127.
[55] Bigelow, "Report," 138.
[56] Ibid., 140. In addition to the three, a few minor ones were also mentioned, such as the Section on Oceanography of the International Geodetic and Geophysical Union. Bigelow, "Report," 141.
[57] Bigelow, "Report," 137.

> researches of the Fisheries Services to insure that the cruises of all shall correspond as to date, as to methods and as to subjects of study, etc; entrusted too, with allocating to each nation the part of the sea to be covered by it, and with choosing the fisheries problems for which each nation should be primarily responsible. The following list of nations that subscribe at present to the council shows how widely inclusive it is: Germany, Belgium, Denmark, Spain, France, Great Britain, Irish Free State, Italy, Norway, Holland, Poland, Portugal, Sweden, Finland, and Latvia.[58]

The countries participating in the ICES operated research vessels, maintained oceanographic laboratories, and carried out surveys, measurements, and collections at stations on a periodic basis within the allotted areas of the sea, and the result of their research was shared by all.

In addition to spurring oceanographic research in each participating country, the ICES had more positive effects on the development of oceanography. First, to ensure the common use of the data collected in each country, the ICES facilitated the settlement of standard methods and techniques in oceanographic work. And, second, through the network and cooperative projects of the ICES, new theories and techniques developed in one place were disseminated quickly to other places. One such example was the ocean dynamics developed largely in Bergen, Norway, by Vilhelm Bjerknes and his colleagues. The role of the ICES was appreciated and admired not only by those involved in the programs directly related to it. Its influence went beyond the participating countries, and even reached across the Atlantic Ocean to those marine scientists in the United States. Bigelow admits that his study of the Gulf of Maine too was “a program modeled on that followed by the International Council for the exploration of the sea in the Northeastern Atlantic.”[59]

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[58] Ibid., 138.

[59] Ibid., 97. Even before Bigelow set about the plan for the Gulf of Maine project, there were many other American marine scientists who were impressed by the ICES program. William Ritter’s research program, mentioned earlier in Chapter 2, admittedly was inspired by it. William E. Ritter, “The Marine Biological Station of San Diego: Its History, Present Conditions, Achievements, and Aims,” *University of California Publications in Zoology*, 9:4 (1912): 137-248.

Despite its admirable achievements, the ICES program had serious weaknesses as well, Bigelow contends. First, with all the participating countries conducting periodic surveys, data—both physical and biologic— accumulated so fast that it was impossible to process them in a timely manner. As a result, the needed "systematic analysis … has not kept pace with the accumulation of facts …."[60] More serious shortcomings resulted mainly from the fact that the program was aimed at solving the fisheries problems. Even though there existed the general consensus that physical conditions at sea greatly affected the lives of fishes and that, therefore, the knowledge of them were essential for the understanding of the life histories of major food fishes, serious research programs in physical and chemical oceanography were often omitted and "physical oceanographers [were] seldom included within the staff of investigators in European fisheries services." So, when expertise in physical oceanography was needed, "it [had] frequently been necessary to relegate the discussion of physical data to scientists not directly connected with them, or with the council."[61] Although it was true that the ICES, in early years, did contribute to some extent to the development and dissemination of the physical theories of the ocean currents, it at the same time restricted the physical oceanography's potential to grow into a fertile field in itself as well as the possible assistance it would be able to give to the fishery studies. Bigelow writes:

> We must point out, however, that the development of oceanography in Europe has been somewhat one-sided during the past quarter century, from the intellectual standpoint. This has been largely due to the dominating role played by the Permanent International Council for the Exploration of the Sea [*sic*], the main object of which is to develop the sea fisheries on a scientific basis, and which consequently has tended to keep biologic problems in the foreground, often at the expense of the physical and chemical aspects of the sea that are the rational basis for a correct understanding of marine biology. In the regular investigations carried on by the fisheries services of the subscribing governments, the tendency has been to take up physical oceanography only to the extent

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60 Bigelow, "Report," 139.
61 Ibid., 139.

> that it may be expected to have direct bearing on fisheries problems, with the result that hydrographic data have not always been chosen most wisely for the solution of physical problems. Though the work of the International Council has contributed materially to the quantitative knowledge of the circulation of the waters off western and northern Europe, it would have contributed still more to the general understanding of the natural economy of those seas had the physical and chemical features been given consideration equal to the biologic in the arrangement of the investigational programs.[62]

According to Bigelow, the neglect of physical oceanography was, in fact, a rather general phenomenon in Europe. It was not a problem confined just to fishery studies in general and the ICES program in particular. "The physical aspects of Oceanography" writes Bigelow, "have also long suffered to some extent in Europe, from another prevailing tendency (the origin of which we do not pretend to explain) to regard them as subservient to oceanic biology rather than to give them the importance that they deserve as a branch of geophysics."[63] As mentioned earlier, Bigelow firmly believed that a genuine development of a scientific field depended on whether that science acquired an independent status or not. Therefore, the European tendency to think of physical oceanography as a subsidiary science to oceanic biology greatly impeded the advance of not only physical oceanography but also the ocean sciences as a whole.

4.2 Oceanography in the United States

It did not take long before oceanography in North America overcame the period of being "dead." Bigelow contends that several events in the 1900's and the 1910's marked the "reawakening" of American oceanography, or the beginning of "Modern Oceanography in America."

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[62] Ibid., 141-142.
[63] Ibid., 142.

> As is so usually the case, the first evidences of this reawakening were not only several, but these several nearly simultaneous. Modern Oceanography in America may, we think, be dated from the following events: the establishment, in 1904, of The Tortugas Laboratory of the Department of Marine Biology of the Carnegie Institution of Washington; the adoption of a regular program of oceanographic study at the Scripps' Institution for biologic research at La Jolla, California in 1908; the institution in 1908 of studies of the bottom sediments, shore line geology and physics of the waters around Florida and the Bahamas, of which the Committee on Sedimentation of the National Research Council was an outgrowth; the inception of the cooperative study of the natural economy of the Gulf of Maine by the U.S. Bureau of Fisheries, and the Museum of Comparative Zoology in 1912; the development since 1910 of oceanic biology as a major project at the St. Andrews Laboratory of the Biological Board of Canada leading directly to the Canadian Fisheries expedition in 1915; and the inclusion by the International Ice Patrol of studies of oceanic circulation as part of its regular duties since 1914.[64]

By the time Bigelow was writing the Report, therefore, there were many exploring projects, both one-time and periodic, going on and a number of institutions working on at least one aspect of oceanography. The most notable exploring project at that time was the ongoing cruises of the *Carnegie* of the Carnegie Institution of Washington, which was "planned for three years, to cover a net-work of 110,000 miles across all the great oceans." The *Carnegie* was intended to cover virtually all areas of oceanography in addition to its regular work on magnetism.[65]

More important, however, than the one-time expeditions for the advance of American oceanography were the intensive studies of the sea. According to the Report, "it is by the method of periodic surveys of definite areas, or by continuous attack on definitely limited problems, that Oceanography in American waters is most rapidly

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[64] Ibid., 94-95.
[65] Ibid., 95; Schlee, *The Edge of an Unfamiliar World*, 266-272.

advancing at present, and may be expected most rapidly to develop in the future."[66] First, at the American Northeast, Canadian agencies had been carrying out regular survey programs. Canadian Hydrographic Service had been working on hydrographic surveys, collecting mostly physical and magnetic data, while the Biological Board of Canada, whose main mission was fishery studies, worked on both physical and biologic surveys. The International Ice Patrol, which was operated by the U.S. Coast Guard, studied the circulation of water masses using the most up-to-date methods of dynamic oceanography. Bigelow also mentions the Gulf of Maine study jointly conducted in the previous sixteen years by the U.S. Bureau of Fisheries and the Museum of Comparative Zoology of Harvard University, of which he himself was in charge.

On the West Coast, he first mentions the oceanographic program of the Scripps Institution. "Oceanography is well served in the coastal belt along southern California, and for a couple of hundred miles out to sea, by periodic cruises of the Scripps Institution of Oceanography of the University of California …." From Bigelow's scattered remarks throughout the Report, it is easy to notice that he regarded this project as the best example of oceanographic work ever undertaken in the United States, even better than his own work at the Gulf of Maine in some respects. He writes that the Scripps Institution's scientific cruises "constitute the most extensive continuing program of the sort now in progress off the Pacific Coast of North America."[67] He also writes that "The Institution's efforts represent, in fact, the most successful project of this sort yet undertaken by any American agency since the days of [Matthew Fontaine] Maury."[68] Other projects were also going on at the Pacific Coast. The Friday Harbor Station of the University of Washington had been increasingly involved in oceanographic work, including studies of oceanic chemistry, physics, and plankton studies. Also, "the International Fisheries Commission, operating under treaty between Canada and the United States, has undertaken a program of sub-surface sections off the Alaskan coast . . . ."[69] There was also a newly established program in California: the Hopkins

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66 Bigelow, "Report," 96.
67 Ibid., 98.
68 Ibid., 99.
69 Ibid. The International Fisheries Commission, now called the International Pacific Halibut Commission, was an outcome of the Convention for the Preservation of the Halibut Fishery of the Northern Pacific Ocean, signed on March 2, 1923 by the United States and Canada. Committee on the Applications of Ecological Theory to Environmental Problems, NRC,

Marine Station and the California Fish and Game Commission jointly embarked on a program of oceanic research concentrating on biological aspects.

In North America, there were a number of scientific institutions where some work related to oceanography was being conducted, although the number was rather modest compared with Europe. "[T]his development [the prospering of marine institutions in Europe]," writes Bigelow, "which (as we now see it) is the climax of a process extending over more than half a century, has had its counterpart on a smaller scale in America."[70] Among those American marine institutions, only a few were considered by Bigelow to have developed fertile oceanographic programs. Of those, the Scripps Institution certainly ranked at the top. He writes that "The Scripps' Institution of Oceanography of the University of California occupies a position at present unique in American oceanography, because it is the only establishment on the continent that is expressly organized and maintained for the investigation of the problems of this science, without economic bias."[71] No other American institutions at the time paid as balanced attention to all of the oceanographic branches as this west-coast institute, with the genuine method of the "intensive study." Without doubt, therefore, "By tradition, and present activity, the [Scripps] Institution leads Oceanography on the Pacific coast."[72]

With the exception of Scripps, American oceanography still depended heavily on the federal agencies, particularly the U.S. Bureau of Fisheries and the U.S. Coast and Geodetic Survey. With their well-equipped survey vessels, they were undeniably in the foremost position to carry out oceanographic surveys at sea. Bigelow himself benefited from the cooperation with the governmental agencies while carrying out his own oceanographic research in the 1910's and 1920's. Citing Congressional Acts that mentioned "the use of the Scientific and Technical research facilities of the Government by private investigators or institutions," he notes that "it is not too much to state that the United States Government is definitely committed in advance to the general policy of cooperation in scientific undertakings as a whole."[73] In the past, these two agencies had

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Ecological Knowledge and Environmental Problem-Solving, 137-150.

[70] Bigelow, "Report," 137.

[71] Ibid., 101.

[72] Ibid., 101-102.

[73] Ibid., 112. See also *Supplement to the Revised Statutes of the United States*, Vol. 2, 1892-1901, pp. 71-72; and *Deficiency Appropriation Act*, Chap. 831, Vol. 2, 1892-1901: *Supplement to the Revised Statutes*, p. 1532.

sometimes been involved directly in scientific activities under exclusively strong leaders, but generally such deviations from their regular duty of more practical work were only rare exceptions.[74]

Despite the strong potential and abundant resources of the federal agencies, they were largely restricted from participating actively in oceanographic programs because of their busy schedule of regular duties and their tight budget. As a result, it was impossible for them to initiate and lead oceanographic research programs not directly related to their practical duties. The U.S. Congress would generally not allow funding for such 'purely' scientific projects. "Thus," writes Bigelow, "the proposed Naval Oceanographic Expedition planned at the Conference on Oceanography held at the U.S. Navy Department in the summer of 1924, failed of fruition because it demanded a large grant from Congress which was not forthcoming, and which, in fact, there was no reason to expect would be forthcoming."[75] Therefore, money and initiative had to come from somewhere else, from the non-governmental sector. Bigelow observes that "Under present conditions private institutions, alone, or the state universities, can originate and carry on a coordinated attack in this field, and it is by helping to fill this gap that the proposed Institute would have its greatest usefulness."[76]

The cooperation between private institutions, or institutions affiliated with universities, and the governmental agencies would, thus, prove fruitful, if carefully planned and managed. Bigelow is confident that "they [the agencies] are in a position to offer practical assistance of various sorts in any large plan for oceanographic study that might be initiated elsewhere under authoritative auspices." To realize such a fruitful cooperation, "What is needed is a definite estimate of the fields in which the several bureaux can lend active aid and of the amount of such assistance that can actually be expected from each."[77] The first and foremost assistance that Bigelow expected from the federal agencies was research vessels. He writes that

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[74] Hugh Richard Slotten, *Patronage, Practice, and the Culture of American Science: Alexander Dallas Bache and the U.S. Coast Survey* (Cambridge: Cambridge University Press, 1994); Dean C. Allard, "The Fish Commission Laboratory and Its Influence on the Founding of the Marine Biological Laboratory," *Journal of the History of Biology*, 23 (1990): 251-270; E. F. Rivinus and E. M. Youssef, *Spencer Baird of the Smithsonian* (Washington, D.C.: Smithsonian Institution Press, 1992).

[75] Bigelow, "Report," 111. See also Weir, *An Ocean in Common*, 21-52.

[76] Bigelow, "Report," 112.

[77] Ibid.

> … the proposed Institute might thus arrange joint periodic cruises along representative profiles in the Atlantic Basin off the United States of just the sort that are most needed to show the secular changes that take place there, not only in the physical state of the water, but also in its organic communities.[78]

It is not clear whether Bigelow, and the members of the Committee on Oceanography, had a plan at that moment for the new institution's own research vessel *Atlantis*. The Report says virtually nothing about the possibility of the proposed institution owning and operating its own ship and just emphasizes the desirability of maintaining close relationships with government agencies that possessed ships which might be used for cooperative oceanographic research. For the matter of chartering of ships for oceanographic purposes, the Bureau of Fisheries and the Navy were the most important for "No federal institution of the United States, other than the Navy and the Bureau of Fisheries, can now spare ships from their regular duties for more than a short time."[79] But, to use governmental ships in scientific researches, additional funding had to be allocated from some outside sources, because "Under present conditions no governmental agency, whether Canadian [or] United States, is able, without contributions of outside funds, to send a ship on special cruises of any great length, unless these can be combined with regular duties."[80]

The U.S. Bureau of Fisheries, in many respects, was the best partner to work together in oceanographic research programs, as its original duties overlapped in many areas with the oceanographers' work. The close proximity of fishery studies to oceanography had been clearly demonstrated in the work of the ICES, and this intimate relationship had indeed contributed to the development of oceanography also in the United States for many decades. Thus, Bigelow writes that "The Bureau of Fisheries stands in a position toward Oceanography different from any other governmental institution in the United States, for its entire program of research, and of conservation of

78 Ibid., 114.
79 Ibid.
80 Ibid., 113.

the marine fisheries, is intimately bound up with basic oceanographic programs."[81] In particular, the Bureau surpassed other agencies in three aspects: first, it possessed well-equipped seaside facilities adequate for all areas of oceanographic work done in laboratories; second, it had workers well trained in branches of oceanography; and finally, and perhaps most important, it had ships "capable of long-sustained cruises with a well arranged laboratory fully equipped for dredging, towing and other biological work as well as for the ordinary routine observations of temperature, salinity, etc., and manned by a personnel fully trained in oceanographic procedure."[82] One problem with the Bureau as a partner in oceanographic programs was that, because of its mission, its cruises were mostly confined "to the waters over the continental shelf, in comparatively shallow water and near land, where practically all the important fisheries are located …."[83]

What was more promising than executing long-term investigations of the sea jointly with the governmental bureaus was to carry out "special observations" of oceanic phenomena "as an incidental or secondary program on [governmental] ships employed on other duties." In fact, "It is under this heading that cooperation with the Government may be expected to prove most productive," according to the Report.[84] All of the governmental agencies in the United States and Canada related in some ways to oceanography agreed to offer this kind of service to private oceanographers and oceanographic institutions, when inquired by the Committee. In fact, its effectiveness was already proven by the cooperative network that the Scripps Institution formed with several agencies. That network had been working quite successfully for several years.[85]

In the Report were mentioned the Bureau of Fisheries, the Navy, the U.S. Shipping Board, the Coast Guard, the Coast and Geodetic Survey, the Geological Survey, the Lighthouse Service, the U.S. Bureau of Standards, and some State organizations on both coasts of the United States. All of these agencies were able and willing to offer help to oceanographers in one way or another according to their situations. In addition to

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[81] Ibid., 121.
[82] Ibid., 122-123.
[83] Ibid., 97-98.
[84] Ibid., 115.
[85] Ibid., 116. See Chapter 3 for details of the network. See also Elizabeth N. Shor, "The Role of T. Wayland Vaughan in American Oceanography," in Sears and D. Merriman, *Oceanography: The Past*, 127-137.

aiding in long-term or incidental work at sea, some organizations were able to offer different kinds of assistance essential to oceanographic researches. As they maintained on-land facilities and laboratories throughout the Atlantic and Pacific coasts, they could be used as temporary headquarters during marine investigations.[86] The help expected from the Bureau of Standards was unique, and very important. "In the field of instrumental development—one of the most important in modern Oceanography—," writes Bigelow, "the prospect for governmental assistance is equally rosy, for the U.S. Bureau of Standards offers unique laboratory facilities, and already has in successful operation a plan for cooperative research in this field."[87] At the laboratory of the Bureau, experts would help developing and improving oceanographic instruments of precision that no other place could offer.

One of the characteristics of the Report is that it covers not only the United States but in most cases deals with North America that included Canada. This coverage certainly resulted from the oceanographers' point of view that the sea has no boundaries, and revealed the necessity of international cooperation in America comparable to that in Europe. But at the same time it also shows the degree of interest and familiarity on the part of those who had been involved with the Committee, including Wickliffe Rose, Frank Lillie, and Bigelow, in the Canadian governmental establishments, their personnel and projects.

The Biological Board of Canada, admittedly the leader in Canadian oceanography, closely resembled those European governmental agencies devoted to hydrographic and biologic studies more than any American institutions "in the scope of their activities, and in their organization."[88] The Biological Board of Canada operated stations on both Atlantic and Pacific coasts: "The Laboratory of the Biological Board of Canada at Nanaimo, B.C. is the headquarters on the Pacific coast of Canada, for participation by various universities in the marine investigations of the Board, just as St. Andrews Laboratory is in the Atlantic coast."[89] The Biological Board of Canada, like the U.S. Bureau of Fisheries and the Fishery Services of European nations, focused on

[86] Bigelow, "Report," 117.
[87] Ibid.
[88] Ibid., 136. For the Biological Board of Canada, later called the Fisheries Research Board of Canada, see Jennifer M. Hubbard, *A Science on the Scales: The Rise of Canadian Atlantic Fisheries Biology, 1898-1939* (Toronto: University of Toronto Press, 2005).
[89] Bigelow, "Report," 102.

the problems of fisheries and related biological studies. But it was freer than its U.S. counterpart in pursuing "investigations in the more theoretic fields of oceanic biology, and in physical oceanography, the practical bearings of which may seem remote." It resulted from the "differences in organization" compared with the U.S. Bureau of Fisheries.

> In these biological laboratories [of the Biological Board of Canada] a system has been developed by which students and instructors from Canadian colleges and universities actively participate in the investigations of the board, under such direction as the case demands. Special attention has, in fact, been directed to the laboratory method of attacking oceanographic problems, resulting in a type of cooperation with educational institutions that may be taken as a model.[90]

That cooperative relationship benefited both sides, the Biological Board and the educational institutions participating in the program. For the students of Canadian colleges and universities working at the laboratories of the board, it was a great opportunity for "supervised research, leading to degrees." Bigelow comments that "this opportunity, largely taken advantage of by students from most of the important Canadian schools, is an especially fertile contribution to the problem of oceanographic education in America today."[91]

Why is the case of Canadian marine science taken so seriously in the Report, and the Biological Board of Canada considered as the most successful oceanographic institution in North America? The first answer has to be that the members of the Committee and Bigelow truly admired the success and effectiveness of the Canadian system. Bigelow on one occasion writes that "the excellence of its [Biological Board of Canada] investigations is internationally recognized."[92] But, Bigelow and others may also have aimed at stimulating the national pride of their fellow Americans by emphasizing the Canadian superiority. Trying to secure support for oceanographic programs in the United States, and hopefully for a brand new oceanographic institution

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[90] Ibid., 132.
[91] Ibid., 109.
[92] Ibid., 132.

on the east coast, they perhaps sought to emphasize the urgent need to boost the research and teaching of oceanography in their own country in order to elevate it to the level of its rival countries. The third, and probably the most important, answer would be that the Committee considered the Biological Board of Canada as a model for the proposed American oceanographic institution, especially in the way it built the productive relationship with colleges and universities. Education, in fact, was a big problem for American oceanography, and the Committee hoped that the new oceanographic institution could contribute to solving that problem. The prospect of adopting the Canadian model certainly seemed promising.

5. Problems and Obstacles for American Oceanography

Summing up the chapter on the "Present Situation in Oceanography in America," Bigelow concludes that "Oceanography is today a "live" science in America, but at the same time an "infant" science, struggling against many and serious obstacles to its growth." American oceanography, indeed, had many problems and obstacles. There were only two things that were sufficiently well maintained for oceanography's further progress: libraries and opportunities for laboratory work. Except for the two, "in every other way Oceanography, though very much alive, lags far behind all the other sciences with which it is commensurate in importance."[93]

Among the problems that American oceanography faced nothing was more serious than the deficiency in its manpower. The number of oceanographers in North America was so few, even when those in Canada were included, that research in many areas of the marine sciences could hardly be expected to be carried out successfully in a continuous manner. According to the "Liste des oceanographes" compiled by the International Geophysical Union in the years between 1925 and 1927, there were 124 oceanographers in the United States and Canada. This number included all whose interests touched an aspect of the ocean sciences and, thus, for many of them

[93] Ibid., 110.

oceanography was not their primary field. The American Geophysical Union's Section of Oceanography had only 31 members in 1927, which "include[d] practically the whole roster of American Physical Oceanographers, as well as several whose interests [were] primarily biologic." The Report continues,

> Probably it is safe to assert that the number of students in North America whose studies are devoted to the physical, geologic, chemical or biologic aspects of the ocean as an entity, as contrasted with those whom the oceanic aspect of the projects in which they are engaged is secondary, is not greater than fifty, all told. And fewer still are actually engaged in oceanographic investigation.[94]

Bigelow also mentions later in the Report that the number of American, and Canadian, oceanographers outside the governmental establishments did not exceed fifty, and that those within the various governmental agencies would number about thirty five.

The very small number of American oceanographers meant that most of the institutions engaged in oceanic studies had "only one or two oceanographers on their staffs, or none at all." It inevitably resulted in the instability of most American oceanographic programs, which had to be abandoned completely if the person responsible for a project lost interest in it or had to leave it for some other reasons.[95] Often, it was extremely difficult to find suitable staff members when a new oceanographic project was being planned. Bigelow, in the Report, emphasizes that money and ships were desperately needed in order for oceanography in America to advance; yet, "it is of men that there is now the most serious shortage," he adds.[96] Similar contentions were repeated. For example, "If one great need of oceanography today is money, another is men;"[97] and "the scarcity of students in this field has been one of the drags on the development of this science in America."[98]

Why, then, were there not enough oceanographers in America? The most

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[94] Ibid., 109.
[95] Ibid., 145.
[96] Ibid., 108.
[97] Ibid., 145.
[98] Ibid., 119.

apparent reason was that there were insufficient opportunities of getting proper education in oceanography. Another, perhaps more serious, problem was "the fact that there [were] very few professional openings for oceanographers in America, outside the government bureaux, whether in teaching or in research institutions."[99] There were scientists who were trained in other fields who, in a position they retained for their original specialties, touched some aspects of the ocean sciences. But for those who had been trained in oceanography with the hope of finding a job in their field, the reality was harsh "because very few professional openings for teaching or investigation [were] open, except in the very special lines of work carried on in the government science."[100]

How was oceanography taught in colleges and universities? The situation was disappointing. "The general paucity of opportunities for instruction in this general field" of oceanography was "so obvious that it need[ed] no detailed survey for corroboration,"[101] says the Report. Compared with other scientific fields, especially those already well established, ocean science in general was practically not included in the university curriculum at all. So far as higher education was concerned, oceanography was far from an independent scientific discipline until that time, despite the wide public interest in it.[102] It was no better for the specific branches of oceanography as there were "few opportunities for instruction in the basic aspects of ocean geophysics, or in the oceanic phases of biology" in American Universities.[103] The situation of physical oceanography was apparently worse. According to "a cursory survey" by the Committee, "no American University today offers a satisfactory course to undergraduates in oceanic Geophysics, as a concrete and sufficiently inclusive subject."[104] Thus, both general introductory courses and advanced specific courses in oceanography, were not taught at a satisfactory level, especially to undergraduate but also to graduate students. What was desperately needed was "a course of instruction, properly graded upward from the elementary introduction to advanced research."[105] The evident result of the lack of proper university instruction was that oceanographers in America had to be "largely self-

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[99] Ibid., 146.
[100] Ibid., 109-110.
[101] Ibid., 108.
[102] Ibid., 109.
[103] Ibid., 146.
[104] Ibid., 108.
[105] Ibid., 109.

taught."[106]

The way oceanographic courses were taught at universities and colleges also had serious problems for the rearing of the next generation of American oceanographers. Bigelow firmly believed that oceanographers had to be familiar with the sea and be capable of doing work proficiently at sea. To satisfy this requirement, two things were indispensable: that there had to be teachers who were experienced in scientific work at sea; and that the students themselves were given enough opportunities to actually go to the sea and learn by doing some work there. There were, however, not enough teachers who were experienced workers in marine field work in most American universities and colleges. Thus, the Report notes that "but few American Universities now number active investigators in Oceanography among their teaching staffs."[107] Without teachers who were actively engaged in ocean investigations, training students at sea was hardly possible. Bigelow, an ardent advocate of field training at sea, explains the difficulty of cultivating true oceanographers as below:

> Psychology must also be reckoned with. It is essential for the oceanographer to have an intimate firsthand acquaintance with the sea, because this alone can give him the mental apprehension of its vastness and of the complex inter-relation of its internal economics that he requires as the background for his detailed studies, no matter in what field these may fall. Therefore, he must spend some of his days out on the sea; often on a boat far too small for comfort, contending with rough seas, wet and cold; sea-sickness must be no bugbear to him, nor cramped quarters. He must, in a word, be sea-minded, just as a forester must be forest minded. Furthermore, marine explorations at all ambitious are necessarily the work of a party whose efforts the oceanographer in charge must direct; therefore, he must have some of the qualities of leadership; it will be easier for him if he be seaman enough to lend a hand, when needed, and if he have some knowledge of navigation. Practical experience shows that these requirements of

[106] Ibid., 109 and 146.
[107] Ibid., 108.

> personality and especially of love for the sea will always limit the number of budding scientists from whose ranks the supply of oceanographers can be drawn.[108]

The "vastness and … the complex inter-relation of its internal economics" of the ocean was in fact a great barrier to the advance of oceanography, for "if the individual investigator have vision he is apt to stand appalled at the complexity of the problems to which any marine investigation necessarily introduces him; appalled too, at the great extent of the area of sea that must be taken into account." An investigator, then, had to have "more than an elementary" knowledge about many different fields of science in order to analyze and interpret the phenomena that he was dealing with. In reality, it is often not possible for an individual scientist to have enough knowledge and skills in all the areas of science that were needed for his oceanographic project. "For this reason," writes Bigelow, "fertile results in the more basic problems of Oceanography can be expected only through cooperation between individual scientists specializing in different fields, between institutions with different facilities, and between nations fronting on different sectors of the ocean."[109]

In Europe, cooperation in oceanographic research at various levels was effectively facilitated by the presence of the ICES, but in North America there existed no such organization comparable to it. One notable organization in this vein was the North American Committee for Fisheries Investigation founded in 1920. Canada, Newfoundland, France, and the United States were members of this Committee at that time. This organization, which was intended to include fisheries services and other relevant institutions of the countries "that participate[d] in the great sea fisheries of the northwestern Atlantic," had "no executive powers but [was] purely advisory." However, the Report assesses its work in the previous years as very successful, and concludes that "the success it has enjoyed without powers of any sort is one of the strongest arguments for the establishment of the proposed Institution."[110]

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[108] Ibid., 145-146.
[109] Ibid., 146-147.
[110] Ibid., 106. See also Hubbard, *A Science on the Scales*, 90-148. It was also called the North American Committee on Fishery Investigation or the North American Council on Fishery Investigations.

Another difficulty that American oceanographers faced was the scarcity of publishing opportunities. Bigelow reports that there was only one scientific periodical devoted solely to oceanography in America, the one published by the Scripps Institution of Oceanography.[111] The problem with this Scripps periodical was that there was often not enough room for outside contributors. As a result, technical oceanographic papers were scattered in scientific journals of such diverse fields as biology, chemistry, geology, geophysics, and fisheries. This situation was apparently not good for American oceanography, because it made it difficult for oceanography to be seen as an independent and unified scientific field. Also, the difficulty on the part of the individual student to "keep abreast of the work of all his colleagues in various parts of the world" was a serious problem for the development of oceanography in America.[112]

6. "Possible Remedies"

Compared with the complexity of the problems, the solution was rather simple: founding an oceanographic institution at an appropriate location on the American east coast. That institution would be able to function as a vehicle through which most of the problems that American oceanography faced would find solutions, the Committee believed. The necessity of a leading organization was obvious to Bigelow, and the committee, for it seemed to be the simplest and easiest way to improve the situation. By giving multiple roles to the new institution ingeniously and strategically, it could be expected to contribute to the betterment of the many problems in American oceanography, ranging from the lack of proper coordination in ocean researches to the insufficient educational programs. Once the committee agreed upon the basic solution of

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[111] The technical series of the *Bulletin of the Scripps Institution of Oceanography* was first published in 1927. For Vaughan's ideas and his correspondence with other oceanographers regarding the publication, see Letter from Bigelow to Vaughan on February 25, 1924 and Letter from Vaughan to G. W. Littlehales on January 26, 1925, Records of the SIO Office of the Director (Vaughan), 1924-1936, Scripps Institution of Oceanography Archives, University of California, San Diego.
[112] Bigelow, "Report," 147.

founding an oceanographic institution, what was needed then was a careful and detailed discussion on its concrete shape and organization. What kind of institution would best serve the various needs of American oceanography became the main issue of the committee's further discussions. Therefore, the last two and a half chapters of the Report deal with the characters of the proposed institution of oceanography, which would enable it to carry out its duties.[113]

How would the institution contribute to solving the problems of American oceanography? It would, first, carry on active field investigations of various aspects of oceanography and publish an oceanographic journal. And, by maintaining sub-stations at "Arctic waters and oceanic abyss," the institution would be able to deal with diverse oceanic environments. The institution would give opportunities of instruction in "Oceanographic field methods" as well as "in the boat work" to visiting students, some of whom would be able to get the benefit of fellowships. For established researchers at universities, it was expected to function "as headquarters for their summer work" in the field of ocean sciences. Close relationship with universities would enable it to offer research opportunities to them. Finally, "It should constantly make it a primary object to encourage the unification of effort" in various oceanic sciences.[114]

Regarding the educational function of the oceanographic institution, the committee took a rather indirect approach. Unlike the Scripps Institution, which admittedly operated as the department of oceanography of the University of California, the new institution would not set up separate undergraduate and graduate curricula of oceanography within the institution itself. Instead, emphasis was laid on the kind of "support *via* the universities, because [the committee was] convinced that with few exceptions sound advances in any field of knowledge [could] be expected only through them or through research institutions fed by their graduates."[115] Three things were considered: establishing fellowships, founding teaching or research chairs, and "strengthening the oceanographic departments in the universities" that already existed.

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113 The titles of the chapters are, Chapter VI Handicaps to the Development of Oceanography, and Best Remedies; Chapter VII Principles That Should Determine the Type of Organization for an Institution for Oceanography in Eastern North America; and Chapter VIII Considerations That Should Govern the Location of an Oceanographic Institution on the East Coast of North America.. Bigelow, "Report," 143-163.

114 Ibid., 148-149.

115 Ibid., 148.

Through these measures, it was expected that "the opportunities for instruction" would be enlarged and "the professional openings in sea-science in colleges, in universities, and in the seaside laboratories" would multiply.[116] The proposed oceanographic institution would be instrumental in stimulating and supporting such measures designed to improve education in oceanography. The institution would provide the chances of "field instruction in the technical procedure" and "furnish the example of actual investigations for students."

The institution would also be able to play an important role in enhancing oceanographic research and in coordinating the work already being done at several institutions in America. It is interesting that the committee intended that this oceanographic institution, and not a separate organization modeled after the ICES, would "serve … for the stimulation of oceanographic researches in other institutions, and … the development of cooperation between the several agencies already active in that field, private, governmental and international."[117] There certainly was a need for coordinating the scattered efforts at various centers of marine study on the east coast. Scientific study of the oceans had to be a cooperative work by a number of participating scientific institutions because of the scale of work, but there always existed the danger that each institution do the work in its own way regardless of what others were doing. If one of the institutions was in a position to lead the way and to coordinate the whole projects in a systematic manner, by setting up a standard method of data collecting and analyzing and by allotting portions of the sea according to the location and capacity of each institution, the project would be much more efficiently carried out. "A common plan" could be established.[118]

This was one of the reasons why they insisted that the new institution be absolutely independent. The Scripps Institution, for example, despite the fact that it was "rapidly developing into a centre of stimulus in this respect" on the Pacific coast, was not able to coordinate all the oceanographic work being done by separate institutions at the north eastern part of the Pacific Ocean because of its inherent limitation of being a university attachment. It was beyond the ability of an institution that belonged to a state university to coordinate researches being done by the diverse institutions—some private,

[116] Ibid., 147-148.
[117] Ibid., 148.
[118] Ibid., 93.

some governmental, and some even belonging to other nations. Even though the Scripps Institution lacked the function of coordinating, however, oceanography was comparatively well served on the west coast of North America because "the committee on the oceanography of the Pacific, of the Pacific Science association, has proved highly effective" as a coordinating agency.[119] But, it had nothing to do with the situation on the east coast because the two coasts had to be considered "separate provinces" both "on geographical grounds and … existing institutional conditions." So, the NAS Committee on Oceanography's recommendations as to the two coasts were different and irrelevant to each other. For the west coast, it was suggested that "the most effective course would be financially to assist and otherwise to strengthen these [seaside laboratories], combined with the establishment of some sort of inter-institutional board to serve as a clearing house for information, and to encourage cooperation between them." On the Atlantic coast, however, a wholly different approach was needed, for there was no institution "established primarily for ocean researches."[120] Therefore, on the east coast,

> support could most effectively be given through the foundation of a central institution for Oceanography. We are convinced that in the long run, any such institution will benefit this science more by devoting its energies to supporting education, by planning its firsthand investigations to serve as examples, and by encouraging cooperation, than it could by spending its resources on a succession of expeditions, unless these resources were practically limitless.[121]

Only independence of the institution would ensure its function of coordination of oceanographic education and research.

The committee aimed at establishing "an entirely independent foundation," ensuring its independency by giving it proper organization, both "external" and "internal." Discussing the "external organization," the Report suggests that "two aims

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[119] Ibid., 147. See also T. Wayland Vaughan, et. al., eds., *International Aspects of Oceanography: Oceanographic Data and Provisions for Oceanographic Research* (Washington, D.C.: National Academy of Sciences, 1937), xiii-xvii.
[120] Bigelow, "Report," 148.
[121] Ibid.

that might be sometimes conflicting" has to be considered: "(1) to encourage the closest cooperation with other agencies engaged in oceanic research; but (2), at the same time to insure the permanent independence of the institution, lest it eventually become dominated by some one university, or group of universities."[122] It means that the committee wanted to make sure that the institution's independence would never hinder its important role of facilitating cooperation among various east-coast marine institutions. Thus a way to maintain the delicate balance between the two seemingly conflicting aims, independence and cooperation, had to be sought somehow.

In the Report is shown the efforts on the part of the Committee to find adequate models from the already existing marine institutions in both Europe and America. Yet, good models were hard to find as the majority of institutions were in some ways dependent on governments. Bigelow writes that "out of 86 establishments outside of North America that are listed by the International Geodetic and Geophysical Union as occupied with the study of the sea, more than 60 are operated directly as governmental establishments."[123] Among the few independent institutions four received careful consideration: the Stazione Zoölogica at Naples, the Marine Biological Laboratory, the Oceanographic Institute of Monaco, and the Carnegie Institution.[124] The Naples Station provided "laboratory facilities and materials for individual students working on whatever problems they [might] select," and the MBL did the same "with a program of instruction in addition." The Monaco Institute and the Carnegie Institution were more research-oriented, the latter being strictly centered on research while the former had public lecture programs. The committee put aside the last two as they were not appropriate models that could encourage cooperation as their organizations did not allow much participation by

[122] Ibid., 150.
[123] Ibid., 151.
[124] For the history of these institutions, see the articles in C. B. Metz, ed., "The Naples Zoological Station and the Marine Biological Laboratory: One Hundred Years of Biology," *Biological Bulletin*, 168 (Suppl.) (1985): 1-207; Lillie, *The Woods Hole Marine Biological Laboratory*; Jane Maienschein, *100 Years Exploring Life, 1888-1988: The Marine Biological Laboratory at Woods Hole* (Boston: Jones and Bartlett Publishers, 1989); Pierre Miquel, *Albert de Monaco, Prince des Mers* (Grenoble: Glénat, 1995); Christian Carpine, *La Pratique de l'Océanographie au Temps du Prince Albert Ier* (Monaco: Musée océanographique, 2002); and Margaret H. Hazen and James Trefil, *Good Seeing: A Century of Science at the Carnegie Institution of Washington* (Washington, D.C.: Joseph Henry Press, 2002).

outside researchers from universities.[125]

The MBL was selected as the best model for the oceanographic institution because it had "proved itself so admirably adapted to the conditions under which science operate[d] in North America," although some modification was inevitable.[126] MBL's successful tradition of participation by a great number of institutions owed much to the "table system" that it inherited from the Naples Station. The Stazione Zöologica could maintain "its international character" firstly "by the so-called table system, whereby institutions in various countries that subscribed toward the upkeep of the station had the privilege of sending investigators there."[127] The universities and other institutions "that subscribe[d] to the support of the Marine Biological Laboratory … [had], however, no such power to make nominations to the governing board ("Trustees"), all of whom [were] elected by the corporation of the laboratory." Therefore, the "danger of domination by any one university, or particular scientific coterie" could effectively be prevented for the "entire control of the affairs of the institution [was] kept in the hands of the persons interested in its welfare as an independent institution."[128]

Likewise, the proposed oceanographic institution's independence would be guaranteed by the participation of a large number of universities and colleges. The ownership would be "in the hands of a broadly representative corporation, whose numbers [might] be expected to grow, with growing interest in the institution, and [might] eventually come to represent all the institutions in America that [were] actively concerned with the study of the sea." And the actual management of the institution was to be entrusted to "a smaller board, of manageable size, elected from the general membership of the corporation." It was this board that would control the institution's budget and determine its policies.[129]

For the "internal organization" of the institution, MBL could not be a good model for the oceanographic institution, mainly because it had to carry out its own research projects. Moreover, the limited opportunities for conducting researches at sea on a ship necessitated systematic planning of the projects and organizing the work force.

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125 Bigelow, "Report," 153.
126 Ibid., 154.
127 Ibid., 152.
128 Ibid., 154.
129 Ibid.

The MBL, or the Naples, style of 'each scientist doing his own work' would definitely not work well here.

> Obviously such entire personal independence would prove much less fertile at an oceanographical institute, because the necessity of obtaining the raw data for the major oceanographic problems at sea from a boat confines the projects that could be undertaken at any one time to such as could be provided for, jointly, by the station's fleet. This means that the activities, not only of the staff of the institution, but of visiting investigators as well must, so far as major problems are concerned, be directed. And this would apply, in particular, to investigations involving the synthesis of various divisions of science, which it should be the special aim of the institution to foster. It is, therefore, essential that the internal organization provide for direction of the station program, at once efficient, sympathetic, and broad-minded.[130]

On the other hand, the Committee was determined that the internal organization be not too rigid but be "fluid enough to allow evolution." It would therefore be a true challenge for the directorate of the institution to be "rigid enough to carry out an effective program and to provide direction both authoritative and stimulating," but "at the same time loose enough to insure the requisite fluidity." To ensure the fluidity, the institution's programs had to be "built up around men and projects, never around subjects," and it was suggested that dividing the institution "along departmental lines would in the long run be ruinous."[131]

Finally, there was the question of where to build the central institution. It would not take long to notice the strong influence of the Marine Biological Laboratory, or of its director Frank Lillie, in the discussion of the institution's location, as well as its organizational characters. For the location of the main institution, three things were considered. First, it had to be close to existing libraries in order to take advantage of the books and periodicals that had been accumulated so that the institution's resources could

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[130] Ibid., 155.
[131] Ibid.

be saved from gathering them from nothing at hand. Second, the new institution would greatly benefit if it be located near "established laboratories of Physics, Chemistry, and Biology," which meant that the ideal location had to be one of the "great educational centers" on the American east coast. Third, geographic conditions had to be considered as well as natural conditions of the nearby seas. Climate had to be favorable and living conditions good, so that researchers could live comfortably during the summer seasons. Harbor facilities and ship yards had to be near the institution, and the researchers had to have easy access to diverse marine environments by small ships.[132] The region that best fit these conditions was, according to Bigelow, the "Cape Cod—Halifax sector," and within this region Woods Hole in Massachusetts was chosen as the ideal site of the central institution largely because of the existence of the Marine Biological Laboratory and the Laboratory of the U.S. Bureau of Fisheries. The fact that they had been quite successfully doing their job of studying the sea and their living inhabitants for many decades proved the suitability of the area for the oceanographic institution. And, very naturally, close cooperation among the three institutions devoted to marine sciences was expected.[133]

The locations of the two sub-stations were also discussed briefly. The one at or near oceanic abyss was especially mentioned in more detail. The committee suggested that Bermuda would be a perfect location for the sub-station, where the facilities of the Bermuda Biological Station, that had ceased to operate, were expected to be used. If the Station could be reorganized and used as the sub-station, "little or no expense" would be needed for building the facilities.[134] The discussion on the other, arctic, sub-station did not reach an agreement regarding the exact location, but the Report mentions several places in the Canadian arctic region.

After all, at the core of the Committee's recommendation was the plan for an oceanographic institution, which was expected to solve most of the problems that

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[132] Ibid., 156.

[133] Ibid., 159. See also W. D. Russel-Hunter, "The Woods Hole Laboratory Site: History and Ecology," *Biological Bulletin*, 168 (1985) (Suppl.): 197-199; and Philip J. Pauly, "Summer Resort and Scientific Discipline: Woods Hole and the Structure of American Biology, 1882-1925," in Rainger, Benson, and Maienschein, *The American Development of Biology*, 121-150.

[134] Bigelow, "Report," 163. For the station's history, see The Bermuda Biological Station for Research, *The First Century: Celebrating 100 Years of Marine Science* (Bermuda: The Bermuda Biological Station for Research, Inc., 2003).

American oceanography faced at that time. Toward the end of the Report, Bigelow writes:

> The time is ripe for the project just outlined. If a strong oceanographic institution can be established on the Atlantic coast, and those now existing on the Pacific coast be adequately strengthened, we believe that through their cooperation, the interests of oceanographic research in America will continue to receive needed attention in the future.[135]

7. Conclusion

The time was "ripe" indeed. A few months after the submission of the Committee's report, the Woods Hole Oceanographic Institution was officially established.[136] No more discussion was necessary as there had been enough in the preceding years. Nor was there any serious dispute about the character and location of the institution. A full agreement was reached among the parties concerned—leading scientists, related scientific institutions including government agencies, and the Rockefeller Foundation. They were all very well aware of the need for such an institution and were overall satisfied with the scheme presented in Bigelow's report. By the time the report was completed, then, they were ready to begin the actual work of starting up the oceanographic institution.

The Rockefeller Foundation's role was particularly important as the money for building the institution came from it and most of the actual work was done by its officials. The Foundation was extremely supportive of the plan to build the oceanographic institution and did not spare money and efforts needed for the project. In fact, even the scientists involved with the Committee on Oceanography, such as Bigelow,

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[135] Bigelow, "Report," 149.

[136] Henry B. Bigelow, "The Woods Hole Oceanographic Institution," *Science*, Vol. 71, No. 1837 (March 14, 1930): 277-278; "The Woods Hole Oceanographic Institution," *The Scientific Monthly*, Vol. 31, No. 4 (Oct., 1930): 377-378.

were surprised at the speed of all the processes and the scale of financial support from the foundation. Officials of the Rockefeller Foundation fully took over Wickliffe Rose's vision and did what they could to realize it. Rose, who retired in 1928 from both the General and the International Education Boards, died in 1931 just after seeing the WHOI founded.

With the establishment of the WHOI, oceanographers in the United States now possessed full-scale seaside institutions devoted manifestly to oceanography on both coasts of the country. Thereby the foundation of balanced development of ocean researches was successfully laid. Together with those smaller seaside stations and other institutions where oceanography was of only minor interest, scattered throughout the Atlantic and Pacific coasts, Scripps and WHOI would provide chances and facilities of oceanographic research and education for American scientists and students. In the Atlantic Ocean, particularly, American oceanographers could catch up with the work of their counterparts in Europe at a fast pace and contribute to the global cooperative program of understanding the oceans. Oceanography as a scientific discipline was now well established with the two major oceanographic institutions actively carrying on oceanic research projects.

As it was clearly envisioned in the Committee on Oceanography's report, WHOI had very different features and missions from those of Scripps. First of all, WHOI was an independent institution not at all affiliated with any university nor with federal or state government. The difference resulted from the different times and situations in which the two institutions arose. When Scripps grew up as an oceanographic institution, there were few other institutions on the west coast that did oceanographic work and, therefore, the notions of inter-institutional cooperation and coordination were not so important. But for WHOI things were different. Scattered marine scientists and their vulnerable research programs in many places, both governmental and non-governmental, made it inevitable that a coordinating agency like the ICES be established. In order to play that role, WHOI could not be bound to a single university or a governmental agency, and inevitably had to be independent. The existence of many good universities and colleges made Bigelow and others to think that it would be much more effective to induce them to develop educational programs in oceanography than to establish separate degree programs at WHOI. Therefore it is impossible to understand the ideas behind the founding of the WHOI without considering the contemporary east-coast situation.

A central oceanographic institution which played the role of mediating, coordinating, cooperating, and stimulating the research and educational programs in a region very well fit Rose's ideal as shown in the work he did with the International Health Board.[137] He sought to build centers of scientific research and education in European countries and believed that they would influence the regions nearby and eventually contribute to the economy and well-being of their residents. In a similar way, the town of Woods Hole was expected to become a center of American oceanography with the laboratory of the U.S. Bureau of Fisheries, the Marine Biological Laboratory, and the WHOI cooperating. WHOI's research and education programs were intended to influence and stimulate other institutions on the east coast. The oceanographic researches were expected to contribute to the nation's economy by aiding the industries such as fisheries, overseas trade, and weather forecast. Ultimately, American oceanography under the initiative of the WHOI would contribute to the international cooperation of science.

In addition to the scientific needs, therefore, a mixture of several different factors enabled the founding of the Woods Hole Oceanographic Institution, and shaped and determined its character. WHOI was an outcome of the scientific and educational situation of its time and place as well as of the prevalent mode of thinking among the leaders of American society.

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[137] See Robert E. Kohler, "Science and Philanthropy: Wickliffe Rose and the International Education Board," *Minerva*, 23:1 (1985): 75-95; and Simon Flexner, "Wickliffe Rose: 1862-1931," *Science*, 75 (1932): 504-506.

CHAPTER 6
Sailing the Oceans: American Oceanography in the 1930's

American oceanographers struggled to build a modern science of oceanography in the United States since the mid-1910's. Their efforts began to bear fruit from the mid-1920's with the founding of two prominent scientific institutions on the Pacific and Atlantic coasts, first the Scripps Institution of Oceanography and then the Woods Hole Oceanographic Institution. These oceanographic institutions brought with them several features new to the traditional American marine sciences. The study of the physical aspects of the seas became much more important than before, scientists were encouraged to go out to the high seas with better equipped research vessels, and cooperative work mixing several aspects of oceanography was more actively pursued. The new pattern of doing oceanographic work resulted from the ideas that had been prevalent from earlier times among a handful of leaders of American oceanography, such as Henry Bryant Bigelow and Thomas Wayland Vaughan who, as directors of WHOI and Scripps, respectively, contributed to the actual building process of the two oceanographic institutions' research programs and educational schemes.

At the two oceanographic institutions, American oceanography developed fast in the 1930's. With the institutional settings that had been established in the previous decade, American oceanographers could make significant contributions to the science of the sea by doing original researches in every domain of oceanography. In the years between the founding of WHOI and the U.S. entry into World War II, oceanography as a scientific discipline was finally established in the United States, and truly oceanographic work was actively carried out on both coasts of the country. At the same time, the leaders of American oceanography also took actions to establish education and training systems that would guarantee the supply of the new generation of qualified scholars in the field of oceanography. The 1930's was the time when oceanographic research programs and a modern educational system for the students of oceanography were set up.

This chapter will first explore the developments of American oceanography that took place in the 1930's, which set the standard of oceanographic research and education for the American oceanographic community. Then, as a closing reflection on the whole discourse on American oceanography from the beginning of the twentieth century until about 1940, it will try to reflect on the meanings of the institutionalization of the science of the sea in the United States that took place in this period.

1. Oceanographic Researches in the 1930's: The Case of the Woods Hole Oceanographic Institution

Oceanographers at Scripps and WHOI actively pursued the study of the Pacific and Atlantic oceans according to carefully articulated research plans beginning in the 1930's. Having well-defined research programs, the two American oceanographic institutions in the 1930's carried out deliberately planned, systematic study of the oceans, and the scientists who belonged to or were connected to them could work within the research network unlike their predecessors whose researches were often independent and isolated from those of their colleagues. What pioneers of American oceanography previously dreamed of, somewhat apart from the reality of their times, came to be realized at last in this period. With the high-level researches performed by their scientific staff, Scripps and WHOI became world-renowned oceanographic institutes which, by the early 1930's, undoubtedly caught up with their European counterparts.

The oceanographic research plans of the institutions were set up mostly by their directors and, thus, the role of the directors became ever more important in the period of active and intensive ocean research. Scripps directors T. Wayland Vaughan and Harald U. Sverdrup and WHOI director Henry B. Bigelow tried to build strong oceanographic programs at their institutions. The situations they faced as directors of Scripps and WHOI in the 1930's were by no means identical, however. Until around 1930, Scripps was certainly in the forefront of American oceanographic studies as the only institution clearly aimed at the study of the sea with its relatively well-established academic staff and resources. Scripps director Vaughan was well aware of the situation and was confident of his institution's superior position in the United States. When the National

Academy of Sciences Committee on Oceanography recommended the founding of WHOI, Vaughan, who was a member of the committee, readily agreed with the decision which might have meant unbalanced financial support favoring the potential competitor of his own institution.[1] He had no worries regarding the future competition with the younger, east-coast oceanographic institute as he believed that almost thirty years of Scripps' history and experience were not easy to overcome for the newborn institution. In reality, contrary to Vaughan's confidence, it turned out that WHOI soon excelled Scripps in the realm of ocean research with its fully equipped research vessel *Atlantis*. WHOI's director Bigelow was much more experienced than Vaughan in terms of seagoing oceanographic work, and had a clearer vision for his institution's long-term research program. With the substantial amount of financial support from the Rockefeller Foundation, one of the first things that Bigelow did as director was to build R/V *Atlantis*.[2] At that time, Scripps did not own a full-scale vessel which could be used for open-sea research work, and that made a big difference for the two institutions. In terms of full-scale seagoing research, the first became last and the last became first. Bigelow and his colleagues at WHOI took a full advantage of the institution's research vessel *Atlantis* in pursuing comprehensive studies of the high seas, particularly in the western part of the Atlantic Ocean.

The R/V *Atlantis* best represented Bigelow's idea about the kind of oceanographic researches to be done at WHOI. In fact, Bigelow's ardent quest for a research vessel preceded the plan for an oceanographic institution. In his Gulf of Maine studies, it was arranged for him to use the Bureau of Fisheries ships *Grampus* and *Albatross*, but they were not perfectly suited for the kind of oceanographic work Bigelow pursued and were not always available at the time he wanted them because of the Bureau's own working schedule.[3] When the Gulf of Maine project ended, mainly

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[1] Elizabeth N. Shor, "The Role of T. Wayland Vaughan in American Oceanography," in M. Sears and D. Merriman, eds., *Oceanography: The Past* (New York: Springer-Verlag, 1980), 127-137; Helen Raitt and Beatrice Moulton, *Scripps Institution of Oceanography: First Fifty Years* (San Diego: The Ward Ritchie Press, 1967), 108-111.

[2] Susan Schlee, "The R/V *Atlantis* and Her First Oceanographic Institution," in Sears and Merriman, *Oceanography: The Past*, 49-56; For a fuller account of *Atlantis*, see Schlee, *On Almost Any Wind: The Saga of the Oceanographic Research Vessel* Atlantis (Ithaca: Cornell University Press, 1978).

[3] For Bigelow's Gulf of Maine study, see Jeffrey P. Brosco, "Henry Bryant Bigelow, the U.S. Bureau of Fisheries, and Intensive Area Study," *Social Studies of Science*, 19 (1989): 239-264.

because both ships became unavailable in 1924, Bigelow began searching for another ship that would enable the resumption of his ocean research. In that effort he reported to the General Education Board president Wickliffe Rose "On work in Oceanography which can be accomplished by a suitably equipped ship" in 1925, and the plan for the central east-coast oceanographic institution grew out of the idea of building a research vessel for Bigelow and other American ocean scientists.[4] For the founding director of WHOI, the vessel was indeed the first priority, and he quickly arranged for its building in Copenhagen, Denmark. Columbus O'Donnell Iselin, physical oceanographer and Bigelow's former student at Harvard, was appointed the commander of the R/V *Atlantis* and was sent to Denmark to oversee the building and equipping of the vessel. *Atlantis* arrived at Woods Hole in time for the summer's work in 1931.

The existence of *Atlantis* was the main factor in inducing marine scientists to Woods Hole during the summer months because, as Bigelow's own experience testified, they had extremely rare chances of working on a well equipped ship. Unlike Scripps in California, WHOI did not operate all through the year with the resident staff, and was rather similar to its neighbor, the Marine Biological Laboratory, in that it was mostly a summer station for university professors and students.[5] Bigelow himself retained his position at the Museum of Comparative Zoology, Harvard, and he recruited staff members also from the pool of academic scientists who already had positions at their own institutions. Therefore, *Atlantis* also operated mostly during the summer months. Given the very limited number of ocean scientists in the United States at that time, Bigelow adopted the strategy of attracting scientific people who had some interest in the sea and educating them into oceanographers by making them work on *Atlantis*. He

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[4] Harold L. Burstyn, "Reviving American Oceanography: Frank Lillie, Wickliffe Rose, and the Founding of the Woods Hole Oceanographic Institution," in Sears and Merriman, *Oceanography: The Past*, 57-66; Schlee, "The R/V *Atlantis*," 49-51; Henry B. Bigelow, "On Work in Oceanography Which Can Be Accomplished by a Suitably Equipped Ship," Fall 1925, Rockefeller Archive Center.

[5] For the Marine Biological Laboratory's system, see Philip J. Pauly, "Summer Resort and Scientific Discipline: Woods Hole and the Structure of American Biology, 1882-1925," in Ronald Rainger, Keith R. Benson, and Jane Maienschein, eds., *The American Development of Biology* (New Brunswick: Rutgers University Press, 1988), 121-150; Frank R. Lillie, *The Woods Hole Marine Biological Laboratory* (Chicago: University of Chicago Press, 1944); Jane Maienschein, *100 Years Exploring Life, 1888-1988: The Marine Biological Laboratory at Woods Hole* (Boston: Jones and Bartlett Publishers, 1989).

believed that scientists in any field could become genuine oceanographers if they could learn to do their researches at sea. Therefore, the most important task of the director, Bigelow believed, was to make plans and schedules for *Atlantis*'s regular scientific cruises. Each year, he wanted to send on *Atlantis* as many scientists as possible so that they would eventually become experienced, enthusiastic oceanographers. At the same time, he had to make sure that everyone who came to work at WHOI had an equal opportunity. All of the WHOI staff members were required to work on *Atlantis* at least once each year for about 10 days, and Bigelow arranged to send experts of several different scientific fields together on a same cruise expecting an interdisciplinary mixing.[6]

Atlantis was for the WHOI scientists both laboratory and classroom at the same time. Bigelow put emphasis on field work at sea, and *Atlantis* was the main means to get to and stay at the WHOI scientists' working field. They did collecting, measuring, experimenting, and discussing on *Atlantis*, even though more work had to be done on land at the laboratories of WHOI. *Atlantis* was indeed at the center of the WHOI's research program in the 1930's. In the summer of 1930, before *Atlantis* became available, WHOI did not conduct its own research and, instead, supported the *Nautilus* Expedition with its first year's operating budget. It was a submarine expedition that aimed to explore the Arctic Sea under the command of Sir Hubert Wilkins.[7] After Atlantis became available, however, most of the WHOI's research plans were centered around the ship's capacities. With *Atlantis*, Bigelow wanted to continue his Gulf of Maine study first of all, and he regularly sent the ship to the Gulf of Maine for a comprehensive study of the area, which was expected to supplement the preliminary study done in the 1910's and 1920's. The Gulf Stream was also a main research target of the institution. It was Columbus Iselin who was most interested in the physical characteristics of the Gulf Stream and, thus, under his leadership *Atlantis* "made a systematic series of repeated cruises with the objective of obtaining a quantitative description of the Gulf Stream and the physical characteristics of the western North Atlantic."[8]

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[6] Roger Revelle, "The Oceanographic and How It Grew," in Sears and Merriman, *Oceanography: The Past*, 10-24; Schlee, "The R/V *Atlantis*," 51-52.

[7] Susan Schlee, *The Edge of an Unfamiliar World: A History of Oceanography* (New York: E.P. Dutton, 1973), 276-278; George E.R. Deacon, "The Woods Hole Oceanographic Institution: An Expanding Influence," in Sears and Merriman, *Oceanography: The Past*, 25-31.

[8] Revelle, "The Oceanographic," 15-16; Columbus Iselin, "Study of the Gulf Stream," *Science*,

There was also a landmark invention of an oceanographic instrument which opened a new world for oceanographers by enabling them to have a new dimension of information about the undersea physical environment. Measuring water temperatures at different depths and at different locations was a laborious and cumbersome job taking considerable time for oceanographers and others working onboard ships and, because of the innate limitations of the work, existing temperature records of even the most exhaustively studied parts of the seas had inevitable gaps and intervals of space and time. The nearest two stations where water temperature was measured were often several miles apart at best and, with such sparse data, analyses of the movement of the seawater, for instance, had to be very limited permitting only a rough outline. It was almost impossible to attack much smaller-scale phenomena such as the eddy currents. In 1934, Carl-Gustaf Rossby devised an apparatus which was expected to help overcome the situation by allowing continuous measurement of water temperature. It was difficult to make the "oceanograph," as it was called, work effectively at sea, and Athelstan Spilhaus was asked to redesign it. In 1939, Spilhaus was finally able to produce a much improved instrument which he called bathythermograph (BT). A stylus inside the BT was designed to give a scratched profile of water temperature against pressure on a smoked glass slide, thereby producing a continuous temperature-depth record. Maurice Ewing and Allyn Vine then designed the BT's exterior as a streamlined torpedo shape in order to enhance the instrument's capacity at sea.[9]

In addition to changing the practice of oceanographic field work and theoretical research, BT played a significant role in repositioning oceanography within U.S. society. Particularly, beginning in the time of the European war, BT's military usefulness was quickly realized and the American oceanographers, with their scientific abilities and instruments, were soon participating in the Navy's wartime efforts. BT was especially useful for the submarine and anti-submarine operations against the German naval force during the Second World War. For example, effective use of the BT would enable the U.S. Navy to take advantage of the newly discovered "afternoon effect." When naval officers were testing the new acoustic echo-ranging gear in the Caribbean Sea, they

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Vol. 86, No. 2242 (Dec. 17, 1937): 555.

[9] Revelle, "The Oceanographic," 16-17; Naomi Oreskes, "*Laissez-tomber*: Military Patronage and Women's Work in Mid-20th-century Oceanography," *Historical Studies in the Physical and Biological Sciences*, 30 (2000): 373-392.

found that the equipment was not working satisfactorily in the afternoon when the surface water was warmed while it worked quite well in the morning and at night. They suspected that the cause might be biological, but could not go further with their limited scientific expertise. *Atlantis* was sent down to the Caribbean, and soon Columbus Iselin and Maurice Ewing discovered that the effect was caused by the downward bending of the sound waves which formed an acoustic "shadow zone" during the daytime when the surface water was heated. They also demonstrated that the afternoon effect and other sonic phenomena could be detected and utilized for naval operations by using the bathythermograph. Iselin, WHOI's second director, thought the close relationship with the Navy beneficial for both, as the oceanographers would help strengthen the country's military capacities during the war and the Navy patronage would eventually improve his institution's financial circumstances. With the outbreak of World War II, oceanographers' participation in the Navy intensified and American oceanography was gradually recognized as a military science.[10]

At Woods Hole, such wide array of topics as "the role of bacteria in the cycle of life in the sea," "methods for the determination of dissolved organic carbon and nitrogen in sea water," and "marine erosion of glacial deposits in Massachusetts Bay" were also actively studied during the 1930's.[11] Although WHOI began almost thirty years later than Scripps, it caught up with the older competitor very quickly and soon excelled it especially in the domain of open ocean research. Henry Bigelow's research experience and his firm belief that oceanography had to be studied at sea contributed to the early achievement of the institution.

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[10] Gary E. Weir, "Fashioning Naval Oceanography: Columbus O'Donnell Iselin and American Preparation for War, 1940-1941," in Helen M. Rozwadowski and David K. van Keuren, eds., *The Machine in Neptune's Garden: Historical Perspectives on Technology and the Marine Environment* (Sagamore Beach, MA: Science History Publications, 2004), 65-91; Revelle, "The Oceanographic," 19-22; Oreskes, "*Laissez-tomber*," 375-378; "The Woods Hole Oceanographic Institution," *Science*, Vol. 92, No. 2385 (Sep. 13, 1940): 233-234.

[11] Schlee, *The Edge of an Unfamiliar World*, 279.

2. Harald U. Sverdrup and His Reform of the Scripps Institution in the 1930's

In the early years of the 1930's, Scripps Institution was in a much different situation from WHOI in several respects. One of the main differences was aptly pointed out by Roger Revelle:

> As is well-known to many of you, the Woods Hole Oceanographic Institution did not slowly evolve from small beginnings as did the Scripps Institution, which began as the Marine Biological Association of San Diego with a gift of $1300 from interested San Diego citizens, and was still relatively impoverished when it became the Scripps Institution of Oceanography in 1924. Instead, from a financial point of view, at least, the Oceanographic sprang full-blown into existence like the goddess Pallas Athena, during the year 1930.[12]

T. Wayland Vaughan struggled to transform Scripps from a biological institute to a genuine oceanographic research and educational institution since he came to La Jolla in 1924. But his reform had limits mainly due to the fact that the institution at that time was "impoverished" as Revelle pointed out. Its limited funds had to be spent on maintaining and repairing the old buildings, facilities, and the Scripps Pier, in addition to maintaining the small number of its academic and non-academic staff. Vaughan expected a substantial amount of financial support from the Rockefeller Foundation as a result of the National Academy of Sciences Committee on Oceanography, which would enable an expansion of the institution facilities and research capacity. But it turned out that the amount of money that eventually came to Scripps was meager compared with that which went to WHOI.[13]

It was not only financial shortage that caused Scripps Institution's weakness in ocean research. Despite his admirable ability and efforts as director of the first American

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[12] Revelle, "The Oceanographic," 11. It was in 1925, not in 1924, when the Scripps Institution for Biological Research was officially changed to the Scripps Institution of Oceanography.

[13] For a general overview of Vaughan's directorship at Scripps, see Raitt and Moulton, *Scripps Institution*, 92-127. See also Shor, "The Role of T. Wayland Vaughan," 127-137.

oceanographic institution, Vaughan's leadership showed serious defects particularly in the last few years of his tenure. The fact that the Scripps scientists failed to participate in large-scale oceanographic research projects for more than a decade gave at least some staff members the feeling that Scripps was not doing what it had to do and, thus, was lagging far behind the European competitors and even the newborn Woods Hole Oceanographic Institution. They included longtime Scripps staff members such as W. E. Allen who worked with William Ritter and shared his vision of "organismal" field science at sea. They were dissatisfied with Vaughan's policy of stressing laboratory experimentation, particularly in the domain of marine biology. Vaughan's preference for laboratory science over field science is well shown in his choice of new staff members in marine biology. In the early 1930's, Vaughan hired biochemist Denis Fox and microbiologist Claude ZoBell.[14]

The shortage of operating funds of the Scripps Institution and director Vaughan's favor of laboratory over field together led to a serious defect for the institution's research capacity: lack of a research vessel capable of open sea expeditions. Scripps, in its much longer history, never had such a well-equipped research vessel as *Atlantis* and there were even times when it had no ship at all. Oceanographic work at Scripps often concentrated on the coastal seas, and its study of the open ocean had to rely mostly on the information gathered not by its own staff members but by others including the U.S. Navy, the Coast and Geodetic Survey, the Lighthouse Service, and commercial steamships. Tremendous amounts of data and samples were handed over to Scripps by the arrangements made with those agencies, and they kept the scientists too busy to plan for other lines of study. Within the Scripps Institution there were voices that contended that Vaughan had to recognize the importance of field study in oceanography and that Scripps needed a larger research vessel than the small *Scripps*, former purse seiner[15] purchased in 1925. Vaughan's ill health prevented him, however, from playing a

[14] Ronald 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 (2003): 461-500. For William Ritter's "organismal" philosophy, see Ritter, *The Unity of the Organism: Or the Organismal Conception of Life*, 2 vols. (Boston: R.G. Badger, 1919).

[15] "Purse seiner" is a fishing vessel employing nets that hang vertically in the water, the ends being drawn as a purse so as to enclose the fish. The vessel is equipped with pursing gallows and pursing winches for hauling in the purse lines which close the net after setting. Commission of the European Communities, *Glossarium: Fishing Vessels and Safety on Board* (Luxembourg:

leading role in planning and executing large-scale oceanographic expeditions, and the one ambitious plan of chartering the Carnegie Institution's research ship *Carnegie* could not be materialized because of the ship's unexpected accident just before the Scripps Institution's scheduled expeditions.[16]

Having realized that he could not satisfy the demands of the Scripps staff members, who wanted the director to make the institution more oceanographic, Vaughan felt that it was time to resign from the directorship. The chosen person to replace Vaughan as the Scripps director was Harald Ulrik Sverdrup, a renowned Norwegian physical oceanographer and polar explorer. A student of Vilhelm Bjerknes, he was internationally famous for his achievements in oceanographic, geophysical and meteorological researches as well as for his oceanic and polar expeditions. As far as field research in oceanography was concerned, Sverdrup was certainly one of the best oceanographers in the world. Moreover, having served as the main outside consultant for the National Academy of Sciences Committee on Oceanography in the mid 1920's, the Norwegian scientist was well informed of the situation of American oceanography. As a person who had an extensive experience of oceanographic field study, and who knew the state of oceanography in both Europe and America, he was thought by many to be the one who would successfully set Scripps back on the track of field oceanography and revive its active ocean research.[17]

From the standpoint of Sverdrup, on the other hand, it is not so easy to understand his decision to accept the offer of the Scripps directorship from the University of California. Sverdrup was professor of geophysics at the University of Bergen, "an endowed professorship for which there are no specific duties," which gave him a good income and considerable freedom. And if he wanted to stay in the United States, he had an earlier, perhaps better, chance. Sverdrup had already been offered the first directorship of the Woods Hole Oceanographic Institution, the position which was eventually given to Henry Bigelow after Sverdrup's refusal. Therefore, Sverdrup's final decision to accept the offer from the University of California six years later was in many

Office for Official Publications of the European Communities, 1990), 503.

[16] Raitt and Moulton, *Scripps Institution*, 104-115; Rainger, "Adaptation and the Importance of Local Culture," 463-473.

[17] Raitt and Moulton, *Scripps Institution*, 116-127.

respects an unexpected outcome considering his firm academic position in Norway.[18]

A direct influence on Sverdrup's decision was Bjorn Helland-Hansen's persuasion. Helland-Hansen, who was then director of the Geophysical Institute at Bergen, visited Scripps during the search process for the new director. He was consulted on the candidates for the new directorship at the Scripps Institution and recommended Sverdrup, who was already on the list. After returning to Bergen, Helland-Hansen talked with Sverdrup on the opportunity, and was able to draw his positive response. Another factor that helped Sverdrup to accept the offer was the fact that the University of California allowed him to take the directorship for only three years. The three-year term would ensure his return to the same position and his ongoing work at Bergen. In reality, it turned out that he later extended his stay in La Jolla until he finally left the Scripps Institution in 1948.

There was a more important reason for Sverdrup's decision to come to the Scripps Institution, however. Sverdrup mentioned it during his speech at the National Academy of Sciences meeting in 1938 when he received the Agassiz Medal.

> There is another matter I wish to mention to you. During the last winter in the Arctic, in 1924-25, we used to discuss what we wanted to do after returning to civilization. One of our party wanted to go to Peru, cross the Andes and, instead of drifting with the ice, to drift down the Amazon River on a raft. He did. I used to say that I should like an opportunity to do oceanographic work in the Pacific Ocean. It took me much longer to reach that goal. Although in 1930 I came into intimate contact with the problems of the Pacific through discussion of the excellent data collected by the *Carnegie*, it is only within the last three years that my wish has been actually fulfilled. In 1924-25 I thought of the Pacific Ocean as a pleasant contrast to the Arctic; now I am more than ever impressed by the tremendous amount of work as yet to be done in the Pacific Ocean, and by the fact that, in spite of the pioneering of Alexander Agassiz and Sir John Murray, large areas in the Pacific

[18] William A. Nierenberg, "Harald Ulrik Sverdrup," *National Academy of Sciences Biographical Memoirs*, Vol. 69 (1996): 338-375; Raitt and Moulton, *Scripps Institution*, 116-156.

> Ocean are still completely unknown from the point of view of the oceanographer. . . . The Scripps Institution has a fortunate location and adequate resources for intensive studies of limited areas off the coast.[19]

Despite the many problems and difficulties that the Scripps directorship would cause, Sverdrup seriously wanted to come to the Scripps Institution where he would be able to study the Pacific Ocean directly. The Pacific Ocean was a relatively unknown place for oceanographers at that time, and the knowledge of that vast ocean was badly needed in order to understand the whole oceanic system. Having spent much of his career at the Arctic regions and elsewhere, Sverdrup felt that the Pacific Ocean could be a new challenge worth tackling for the period of three years at a closer distance. The location of the Scripps Institution was more than adequate for this purpose. During his tenure, his interest in the study of the Pacific Ocean continued and even intensified.[20]

As soon as he arrived in La Jolla in 1936, Sverdrup began to reform the Scripps Institution in several directions. Among others, the first thing he did was to find ways to secure a new research vessel for the institution's new research program which was directed at extended sea work. Sverdrup felt that a larger and better-equipped vessel was necessary for a full-scale study of the Pacific Ocean, while using the smaller *Scripps* for short term cruises along the California coast. To discuss the matter, he contacted local members of the Advisory Board, including J. C. Harper, Julius Wangenheim, and Fred Baker. Shortly after Sverdrup began his efforts to get the second ship for the institution, however, an accident happened, which made the situation even worse. In November, 1936, there was an explosion on *Scripps* and the ship sank immediately. Instead of having a second, much better one, Sverdrup and his institution lost the one they already had. Since the accident, the Scripps Institution had no ship at all until Robert P. Scripps, E. W. Scripps's son, purchased a yacht for the scientific use of the institution in April, 1937. The 104-foot auxiliary schooner was rechristened the *E. W. Scripps*, and became available for the use of the Scripps Institution on December 17, 1937 after some

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[19] Harald Ulrik Sverdrup, "Response by the Medalist," *Science*, Vol. 90, No. 2324 (Jul. 14, 1939): 26-27.

[20] H. U. Sverdrup, "The Currents of the Pacific Ocean and Their Bearing on the Climates of the Coasts," *Science*, Vol. 91, No. 2360 (Mar. 22, 1940): 273-282; "The Pacific Ocean," *Science*, Vol. 94, No. 2439 (Sep. 26, 1941): 287-293.

remodeling and installing of scientific equipment. Having gone through such troubles in the first year of his directorship, Sverdrup now had a ship of appropriate size and seagoing capacity to implement his research program.[21]

The first opportunity came with an offer from the California Division of Fish and Game in 1937, which was even before *E. W. Scripps* was ready. Although Sverdrup had not worked in relation to the fisheries problems in the past, he readily recognized that this request from the state fishery agency could give him and his institution a good chance to try a new model of ocean research. In order to understand the reasons for the declining catches of sardines in the California coastal seas, scientists at the state agency wanted aid from the Scripps oceanographers regarding current patterns and other physical properties of the area, which might have influenced the spawning and the drift of fish eggs and larvae. Specialists of biological aspects of fish, they wanted assistance from the Scripps Institution particularly in physical oceanography. Sverdrup accepted to participate in the California Division of Fish and Game's project, and the Scripps scientists could work on the Fish and Game ship *Bluefin*.[22]

The Fish and Game sponsored study that began in 1937 set the standard for later research projects of the Scripps Institution. At the same stations, basic oceanographic properties such as water temperature, salinity and dissolved oxygen were measured repetitively, and the data and samples were analyzed by the Scripps staff members and their assistants. In particular, physical data were used to interpret the movement of seawater by the dynamical method, which gave knowledge about the oceanic current system and the seasonal changes. The California current system, coastal upwelling, eddy currents were better understood thanks to Sverdrup's research program. Similar methods were used again in 1939 and 1940 during the expeditions to the Gulf of California. Chemical, biological, and geological studies were also done in close relation to the physical oceanographic work.[23]

The most important characteristic of the oceanographic work done for the California Division of Fish and Game was that it involved many Scripps staff members of different specialties. Previously, under Vaughan's directorship, scientific work at the

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[21] Raitt and Moulton, *Scripps Institution*, 121-127; Rainger, "Adaptation and the Importance of Local Culture," 474-476.
[22] Rainger, "Adaptation and the Importance of Local Culture," 476-478.
[23] Ibid.

Scripps Institution was largely individualized, each person pursuing his own line of research without linking it with those of his colleagues. The idea that all the natural phenomena of the sea are interconnected did not have much influence upon the scientific work of the institution in reality. In other words, there was no common aim and no overarching research program that encompassed the research projects of each staff member of the Scripps Institution. Vaughan had his personal researches going on, too, even though most of them were temporarily suspended because of the administrative duties of the director. But he did not try to link his scientific work with that of others at the institution, and made no efforts to organize the researches of the Scripps scientists according to a coherent plan. In short, Vaughan was not a builder of a research program, which Sverdrup certainly was. It did not take long for the scientists at Scripps to discover that everything was different with Sverdrup, who not only planned the researches of the Institution where a number of the Scripps members would participate but also actively participated in the cruises, discussions, and led the whole venture himself.[24]

Sverdrup's new research program emphasized and enabled cooperative work among scientists of various specialties, but it did not mean that all the oceanographic branches had equal importance in that program. "[Sverdrup] was the first genuine physical scientist who ever came to the Scripps Institution, a modern geophysicist," Roger Revelle later remarked as to the Scripps director's identity as a physical oceanographer as well as to his preeminence as a world renowned ocean scientist of his time.[25] Sverdrup was basically a physical oceanographer and he thought that it constituted the fundamental part of ocean sciences.

> In the field of physical oceanography, the greater part of the theoretical and practical work can be conducted with little or no attention to results in other marine sciences. Occasionally, conclusions are tested by examining distributions of properties that are influenced by biological activity—for instance, the dissolved oxygen content—but often studies

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[24] Ibid., 480.

[25] Roger R. Revelle, "Preparation for a Scientific Career," an oral history conducted in 1984 by Sarah Sharp, Regional Oral History Office, The Bancroft Library, University of California, Berkeley, 1988. SIO Reference Series No. 88-19. November 1988, 31.

> in physical oceanography can be carried out independently. For this reason several oceanographic institutions, such as the *Institut für Meereskunde* of the University of Berlin, and the Division for Oceanography at the Geophysical Institute, Bergen, Norway, are devoted to research within physical oceanography only, and for this same reason the International Association of Physical Oceanography exists as part of the International Union of Geodesy and Geophysics, and separate from other branches of oceanography.[26]

At the core of physical oceanography was the dynamical theory which, as Sverdrup firmly believed, could yield the understanding of basic features of the ocean and, thus, other oceanographic researches had to be based on the dynamical oceanography. The dynamic theory of ocean currents was developed by Johan Sandström and Bjørn Helland-Hansen in 1903, and this theory was based on the principle that density distribution is dependent on currents and therefore currents can be computed from the density distribution.[27] The density distribution of certain areas of the sea could easily be acquired from the data set of water temperature, depth, and salinity. By placing dynamical oceanography at the center of the Scripps research program, Sverdrup was able to play his role as the leader of the mainstream ocean research at the Scripps Institution, because he, as an expert of dynamical oceanography, was the only person who could manage and control details of the program. And he did participate in the researches as one of the research scientists for research was very important for Sverdrup himself. As already mentioned, he was afraid that administrative duties would interrupt his own research, and it was one of the reasons he had hesitated coming to Scripps. Therefore, despite the necessary administrative work of the director, Sverdrup actively participated in the researches of the institution that he himself planned.[28]

Other branches of oceanography, mostly those that were relevant to dynamical oceanography, were also actively studied within Sverdrup's research program. For

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[26] H.U. Sverdrup, Martin W. Johnson and Richard H. Fleming, *The Oceans: Their Physics, Chemistry, and General Biology* (New York: Prentice-Hall, 1942), 4.
[27] M.P.M. Reddy, *Descriptive Physical Oceanography* (Exton, PA: A.A. Balkema Publishers, 2001), 99-100. See also Brosco, "Henry Bryant Bigelow," 241-243; Sverdrup, Johnson and Fleming, *The Oceans*, 481-515.
[28] Raitt and Moulton, *Scripps Institution*, 120-121.

example, the movement of fish eggs and larvae were studied in close relation to the California current system. The changes in the current and eddy system would inevitably result in the different fate of the eggs and larvae which would eventually cause the increase or decrease of yearly catches of commercial fishes. Not only the study of fish eggs and larvae but also that of the planktons in general (both phytoplanktons and zooplanktons) fit very well with the program. As planktons have no, or very limited, ability to move by themselves, ocean currents largely explained the migration of planktons and, conversely, positions of planktons could often supplement physical oceanography by verifying the theory—showing that they were really there at the anticipated location. Therefore, W. E. Allen rose to a much more important position at the institution than during Vaughan's directorship; Vaughan did not think that his methodology was as effective and up–to-date as that of experimental biologists. With Sverdrup, however, things changed as Allen's plankton studies were easily incorporated into the mainstream work led by the new director. Similarly, Roger Revelle's marine geological work fit well with the program. Revelle led the geological investigations during the Scripps Institution's expeditions to the Gulf of California in 1939 and 1940. He studied marine geology with Vaughan, but was interested in the dynamical theory and he tried to apply it to his work on sedimentation.[29]

Not every one of the Scripps scientists received the benefit from Sverdrup's research program. There were those whose research methods and styles did not match well with the research program centered on dynamical oceanography. Denis Fox and Claude ZoBell's experimental biology which was heavily laboratory oriented did not find its place easily within Sverdrup's program, and the two men and their scientific work were more and more marginalized during Sverdrup's directorship. Likewise, Francis P. Shepard's marine geological work with emphasis on underwater topography did not have much relevance with the mainstream researches of the institution and, unlike Revelle work, remained on the periphery.[30]

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[29] Rainger, "Adaptation and the Importance of Local Culture," 481-483; F. P. Shepard, R. Revelle and R. S. Dietz, "Ocean-Bottom Currents off the California Coast," *Science*, Vol. 89, No. 2317 (May 26, 1939): 488-489. Sverdrup's new approach was widely influential especially among the younger researchers and students at Scripps and elsewhere, and eventually resulted in the forming of a new kind of biological oceanography. See John A. McGowan, "Sverdrup's Biology," *Oceanography*, 17 (2003): 106-112.

[30] Rainger, "Adaptation and the Importance of Local Culture," 485-488; Naomi Oreskes and

During Sverdrup's directorship, the Scripps Institution of Oceanography began to study the Pacific Ocean in a systematic manner, although the efforts had to be limited to a few small areas near the California coast in the first few years. The kind of oceanographic studies carried out by the Scripps scientists in this period were similar to the work done at the Woods Hole Oceanographic Institution in several ways. Both institutions emphasized the importance of field work and research vessels. The effectiveness of the dynamical theory, developed by the Scandinavian geophysicists, was highly valued, and it was adopted as a means to understand the physical conditions of the oceans. Physicists, chemists, biologists, and geologists were encouraged to work together to solve problems of the oceanic phenomena which are always interconnected. These characteristics formed the basic pattern of American oceanographic research in the 1930's, and remained influential thereafter.

3. Education of American Oceanographers

Since the mid-1920's, when the Scripps Institution was transformed into the first American oceanographic institution, finding qualified oceanographers in the United States who could carry out genuine 'oceanographic' researches became an urgent problem for the administrators. It was indeed a problem because there were not many in the country who could be called oceanographers. When Vaughan was looking for a biological oceanographer to fill a position at the Scripps Institution, Henry Bigelow told him that "there ain't no such animal in the U.S.A. You must either import him or bring him up."[31] Oceanography, as envisioned by leaders like Vaughan and Bigelow, was not a synonym of marine science; a scientist who studies an aspect of the sea without considering the relationships within the connected whole could not be a true

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Ronald Rainger, "Science and Security before the Atomic Bomb: The Loyalty Case of Harald U. Sverdrup," *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, 31 (2000): 309-369.

[31] Letter from Vaughan to R.G. Sproul (May 28, 1931). Raitt and Moulton, *Scripps Institution*, 116.

oceanographer. When the Woods Hole Oceanographic Institution was established in 1930, it became more difficult to find suitable ocean scientists from the small pool of American oceanographers.

At the root of the problem of manpower lay the deficiency of proper educational programs. Henry Bigelow wrote in the report of the National Academy of Sciences Committee on Oceanography that American oceanographers had to be self-educated because there were not enough chances for proper formal oceanographic education. The small number of American oceanographers that existed were not educated and trained to be oceanographers at colleges and universities. Therefore, building an education system for those who were to become professional oceanographers had to be a hot issue within the American oceanographic community throughout the 1930's.[32]

To Bigelow and Sverdrup alike, the most effective way to educate the young generation of American oceanographers was to make them participate directly in research as assistants to established scientists, during field work and at laboratory. Formal education was no less important, however, and in this the two American oceanographic institutions took very different approaches. Scripps belonged to the University of California system, and Vaughan used to call the institution the "department of oceanography" of the degree-granting state university. Yet, WHOI was an independent institution which had no formal connection with any educational institution. From the beginning, Bigelow and the WHOI trustees wanted their institution to remain independent from the possible influences from the government, industry, and academic institutions including colleges and universities. Therefore, WHOI had no formal educational program within the institution, nor had it built any official, cooperative relationship with outside educational institutions.

There were two levels of oceanography education and training at WHOI. First, the staff members had to be trained. Bigelow constituted the institution's scientific staff with professional scientists of diverse specialties from a number of different institutions. Many of them had no former experience of doing oceanographic work, and they had to learn to become oceanographers by studying basic knowledge about the ocean and

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[32] Henry B. Bigelow, "Report on the Scope, Problems and Economic Importance of Oceanography, on the Present Situation in America, and on the Handicaps to Development, with Suggested Remedies," Report of the committee on Oceanography of the National Academy of Sciences, Frank R. Lillie, Chairman, 1929, 108-110.

applying their scientific background to the natural phenomena of the sea. Participating in oceanographic field work, especially the *Atlantis*' regular cruises, was an essential factor of this training for the WHOI's staff members.[33]

For the education of future oceanographers, Bigelow and others at WHOI believed that it had to be done basically at universities and colleges, just like other scientific disciplines. Instead of formal education leading to degrees, WHOI awarded fellowships to graduate students interested in oceanography, who were enrolled at various universities, and it enabled them to have chances to work at WHOI with oceanographers of diverse sub-specialties. Generally, twelve such fellows were appointed each year. These student-fellows would learn basic skills of oceanographic researches, both in the field and at laboratories, and their experience would help them to be better prepared for the career in oceanography. Again, the *Atlantis* played an important role for the field education of the student fellows, and in that sense it might well be called the institution's main laboratory and classroom. Bigelow and his colleagues also aimed to stimulate universities and colleges through this apprenticeship system. When their students became the WHOI fellows, the universities were expected to become more interested in the science of oceanography. They would probably organize and strengthen oceanography programs, or at least set up more oceanography courses for their students.[34]

The WHOI took this indirect approach to the problem of education because there were already a number of good universities and colleges on the east coast of the United States. Bigelow and others felt no need to establish yet another educational institution within the WHOI. This situation was very different from that on the west coast where there were fewer universities. WHOI's role in oceanography education was to train as many university professors first by engaging them in the programs of the institution.

WHOI's education policy did not change until the mid-1960's, when the changed circumstances necessitated a new approach. The fellowship system had worked quite well, and it was reported that between 1930 and 1958 "320 fellowships [were awarded] and in the next three years, at an accelerated pace, 141 more." Even though the

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[33] Revelle, "The Oceanographic," 13-14; Schlee, "The R/V Atlantis," 49-56.
[34] Schlee, "The R/V Atlantis," 49-56.

WHOI fellowship was usually a pivotal part in the students' oceanographic education, not much was attributed to the institution officially. The students' graduate "degree was awarded by the home university with little credit other than a footnote to the Institution."[35] It had not been a problem in the 1930's, but was a disadvantage for the institution around 1960. The post World War II era saw a great boom in oceanography, which brought about the founding of many new oceanographic institutions and oceanographic programs at universities. The WHOI trustees decided that the institution had to get involved in the formal education in order to survive the competition. Cooperation with the Massachusetts Institute of Technology was deliberated as the two institutions had been working together in several projects for many years. For instance, WHOI and MIT jointly published "Papers in Physical Oceanography and Meteorology." In 1966, WHOI started to operate the joint graduate program with MIT, and the policy of indirect oceanographic education was finally abandoned.[36]

Formal oceanography education at the Scripps Institution of Oceanography was initiated by Vaughan, who became the second director of Scripps with the mission to make it oceanographic. As he struggled to transform the marine biological station into an oceanographic institution, he soon realized the need for an educational program which had not existed at Scripps, formerly a biological institute. He made up course guidelines for undergraduate students intending graduate study in oceanography at the Scripps Institution, in which he described the number and kind of mathematics, natural sciences, and language courses to be taken. Graduate courses were also established at Scripps, which would be taught by the staff members. Therefore, Sverdrup did not see a total void of oceanographic curriculum at Scripps when he arrived as Vaughan's successor.[37]

Vaughan's oceanography curriculum, both for the undergraduate students of the University of California and the graduate students at La Jolla, was not working satisfactorily, however, to Sverdrup's judgment. Few students were interested in oceanography deeply enough to fulfill the course requirement at undergraduate level, so that it was difficult to find qualified students for the Scripps' graduate program. To

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[35] Paul M. Fye, "The Woods Hole Oceanographic Institution: A Commentary," in Sears and Merriman, *Oceanography*, 1-9.

[36] Ibid., 3-5; George E.R. Deacon, "The Woods Hole Oceanographic Institution: An Expanding Influence," in Sears and Merriman, *Oceanography*, 23-31.

[37] For the establishment of educational program at Scripps during Vaughan's directorship, refer to Chapter 3 of this volume.

remedy the situation, Sverdrup and his colleagues at the institution taught undergraduate courses in oceanography, for the first time, during the summer session of 1937 at the University of California at Los Angeles.[38] Graduate education also needed some reform and standardization. The weekly seminar was led by the staff members in rotation, and the content depended too much on the staff members' own interest. Sverdrup felt that graduate students needed to receive more systematically organized teaching in order to grasp the background knowledge of general oceanography and, at the same time, specialized education in their own sub-field.[39]

Sverdrup and his colleagues realized that an oceanography textbook was necessary to standardize and enhance the level of graduate education at the Scripps Institution, and the task of writing a general oceanography textbook began in late 1938. Sverdrup coauthored the book with chemical oceanographer Richard Fleming and marine biologist Martin W. Johnson, both of whom were assistant professors at Scripps. It was a vast amount of work for the three authors to summarize the whole achievement of the science of the sea that had been accumulated for centuries until that time, and it was more so since the development of oceanography became much faster in the 1930's.

> Four years ago when we started the preparation of this book, we hoped to give a survey of well-established oceanographic knowledge, but it soon became apparent that the book could not be brought up to date without summarizing and synthesizing the wealth of information that has been acquired within the past dozen years, as well as the many new ideas that have been advanced. Consequently, the book has grown far beyond its originally planned scope, and the presentation has become colored by the personal concepts of the authors.[40]

The historic oceanography textbook, *The Oceans: Their Physics, Chemistry, and General Biology*, was published in 1942. More than one thousand pages, *The Oceans*

[38] By this time, Scripps became more intimately connected to the UCLA than the campus at Berkeley, and from 1938 it officially belonged to the Los Angeles campus until the founding of the University of California at San Diego in 1958.
[39] Rainger, "Adaptation and the Importance of Local Culture," 475; Raitt and Moulton, *Scripps Institution*, 125-127; McGowan, "Sverdrup's Biology," 106-107.
[40] Sverdrup, Johnson and Fleming, *The Oceans*, v.

contained the most up-to-date knowledge of physical, chemical, geological and biological oceanography in its twenty chapters. It has long been considered as "the Bible" of oceanography, and its influence can still be felt today.[41]

One of the characteristics of *The Oceans* was that it emphasized the "close interrelation and mutual dependence of the single marine sciences," and much of the first chapter, Introduction, was devoted to explaining and giving examples of the relationship among the four branch fields of oceanography.[42] This emphasis on the interrelation and mutual dependence, together with the fact that it was a general oceanography textbook which encompassed all of its sub-branches, had a clear implication for the readers of the book, both teachers and students. In order to become a good oceanographer, one had to study general oceanography and know basic knowledge and skills of all the sub-fields of oceanography no matter what his/her specialty was. The idea of general oceanography education had a lasting impact on the American oceanographic community for more than a half century as, for instance, WHOI scientist Joseph Pedlosky remarked in 1992:

> The first and more traditional of these [attitudes] sees oceanography as a single unitary whole. All branches of oceanography, i.e., physical, chemical, biological and geological, are seen as closely fitting parts of a single science. The task of education in this traditional view is to make sure each student knows something about all branches of oceanography. This attitude is typified by courses that at least philosophically follow in the pattern of the great oceanographic treatise, *The Oceans* (Sverdrup *et al.*, 1942). This massive text, which runs to over a thousand pages, imposes a suggestion of a basic curriculum in oceanography. It treats all

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41 For example, see the short articles in *Oceanography*, 5 (1992) celebrating the 50th anniversary of the book's publication: D. James Baker, "*The Oceans* 50th Anniversary," 154-155; Walter H. Munk, "*The Ocean* "Bible": Reminiscences," 155-157; Bruce A. Warren, "Physical Oceanography in *The Oceans*," 157-159; Sharon L. Smith, "*The Oceans*—Its Relevance Today in Biological Oceanography," 159-160; Dean A. McManus, "*The Oceans*: The Geological Bookends," 160-162. See also, Walter Munk, "Harald Ulrik Sverdrup (1888-1957): Celebrating the Return of the *Maud* 75 Years Ago," *Polar Research*, 20 (2001): 129-138; John W. Farrington, "Sverdrup, Johnson, and Fleming's *The Oceans* Revisited: What the Future of Graduate Education in Ocean Sciences?" *Oceanography*, 14 (2001): 34-39; John A. Knauss, "The Oceans as Educational Philosophy," *Oceanography*, 16 (2003): 29-31.

42 Sverdrup, Johnson and Fleming, *The Oceans*, 1.

> the subjects described above and has had an enormous influence in our thinking about oceanography education.[43]

The publication of *The Oceans* was perhaps the culmination of pre-World War II development of American oceanography, in terms of the discipline's institutionalization. *The Oceans* book not only contained the achievement of recent researches done by the Scripps scientists but also reflected the new research program Sverdrup established at the Scripps Institution. At the same time, the curricula and contents of teaching for the graduate students at Scripps directly followed the textbook's structure and contents. In that sense, research and education were perfectly linked and institutionalized at the Scripps Institution according to the same philosophy and methodology, and *The Oceans* was the medium and symbol of that accomplishment. Moreover, that phenomenon was not confined to the Scripps Institution alone since the textbook's influence was strong throughout the country. *The Oceans*, as the standard textbook of oceanography, was enthusiastically accepted and used almost everywhere in the United States where oceanography was studied and taught. Those who entered oceanography through studying *The Oceans* naturally absorbed the philosophy and methodology embedded in the book, and when they became oceanographers themselves they did the scientific activities according to what they learned from the textbook. Therefore, it is no exaggeration to claim that the book standardized not only the oceanography education, but also the whole practice of the science of the sea in the country. Oceanography was still a minor scientific discipline in the United States in the 1930's and early 1940's with only a small number of oceanographers, and there were but a few institutions where the research and teaching of oceanography were done. Yet, the common textbook, which standardized the education and practice of the science of the oceans, set the fundamental basis for the future development of oceanography as a unified scientific discipline. With the publication of *The Oceans* and its wide distribution, American oceanography now possessed one of the key factors, which was indispensable for becoming a modern scientific discipline.

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[43] Jeseph Pedlosky, "Graduate Education in Physical Oceanography," *Oceanography*, Vol. 5, No. 2 (1992): 117-120.

4. Conclusion

In the early twentieth century, some American scientists sought to establish the science of oceanography as a unified scientific discipline, in which the physical, chemical, geological and biological studies of the sea were closely linked and interconnected. Building on the foundation of former marine sciences tradition, and somewhat stimulated by the contemporary developments in Europe, early leaders such as William Ritter, Henry Bigelow, and Wayland Vaughan, tried to make oceanography an acknowledged scientific field in the United States. Marine sciences, especially marine biology, were popular within the American scientific community at that time, but marine biologists were more interested in biological problems than the oceanic phenomena *per se*. In that respect, they believed that oceanography had to be a separate, independent science dealing with the scientific aspects of the oceans directly. Their efforts were materialized in the form of oceanographic institutions, on the Pacific and Atlantic coasts.

At the Scripps Institution of Oceanography and the Woods Hole Oceanographic Institution, oceanographers not only did their researches of the seas but also tried to establish the research programs and educational system of American oceanography. Due to their differences in history, organization, regional context, form of financial support, and the kind of research vessels they operated, the two oceanographic institutes naturally came to take somewhat different steps in those developments, and each built its own, unique style of research and education system. The ocean scientists at the two institutions, however, arrived at a consensus on most of the important basic points such as the concept, methodologies, and problems of oceanography, and had a shared vision for its future development. Thus, the foundations for the science of oceanography in the United States were laid in the 1930's, and it can be said that oceanography as an independent scientific discipline was established by the time *The Oceans* was published in 1942. Once American oceanography was established and institutionalized, the scientific study of the oceans was no more sporadic efforts of individual scientists, who were often amateurs, but became a continued, systematic enterprise executed by groups of well educated oceanographers.

For the establishment and institutionalization of oceanography in the United

States, then, the period of about forty years, roughly from 1900 to 1940, was crucial as we have seen so far. The importance of this period did not go unnoticed by many oceanographers. For example, Harald Sverdrup wrote in the Introduction of *The Oceans* in 1942:

> Since 1900, great advances have been made within all of the marine sciences, and the contacts between the special fields have become more and more intimate. The development is due partly to improved technique and partly to the application to the phenomena in nature of theoretical research and results of laboratory studies.[44]

The historical meanings of the first four decades of the twentieth century have not been duly appreciated, however, by historians of oceanography, who often emphasized the great oceanic expeditions in the late nineteenth century, as represented by the famous *Challenger* Expedition, or the unprecedented expansion and militarization of oceanography since the Second World War. In the history of oceanography, the importance of those two great periods is unquestionable, and it is quite understandable that historians took a closer look at them, during which many spectacular events and changes took place. On the other hand, during the forty year span in between the two periods, the development of ocean sciences did not make much noise, and oceanography made a rather quiet internal progress. Not much spectacular news about the science of the sea was heard by the public. The tragic accident of *Titanic* in 1912 and the German U-boat attacks were perhaps the only exceptions, but there was little American ocean scientists could do with them. The outward silence of American ocean science was not an evidence of stagnation, however. Oceanography was quietly making a step-by-step progress that was most needed at that stage of its history.

During the period of the great trans-oceanic expeditions, a unified science of oceanography did not exist even though the name 'oceanography' was coined at that time. Scientists who participated in and were responsible for parts of the scientific work of the expeditions did not think of themselves as oceanographers nor did they consider their collective work as belonging to a single science of oceanography. Largely, their

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[44] Sverdrup, Johnson and Fleming, *The Oceans*, 1.

activities were still more basic survey work and collecting than profound scientific practice. Only through the decades of ocean expeditions and in trying to explain the causes and effects of their findings did the idea that various oceanic phenomena were interrelated emerge slowly. For example, Sir John Murray, who participated in the *Challenger* Expedition and later took over the work of the Challenger Commission after Wyville Thomson's death, came to understand the need for a unified approach to the study of the oceans, and had a strong influence on American ocean scientists such as Bigelow and Vaughan. The recognition that the scientific study of the oceans had to be unified led to the efforts of ocean scientists to build an independent science of the sea, which took place during the first four decades of the twentieth century.

Oceanography, as a scientific discipline formed during that period, then proved its practical value and effectiveness during the Second World War and the ensuing Cold War period. Many of the American oceanographers could contribute to the war effort utilizing their scientific expertise in such domains as analyzing the bathythermograph data and predicting the surf conditions for landing operations. After the end of World War II, the American oceanographic community experienced a great expansion, largely owing to the G.I. Bill. Young men who had become familiar with oceanographic work during the war entered graduate schools to study oceanography. Existing oceanography programs were enlarged and new programs were established in many universities and colleges throughout the country. Oceanography's military and political importance became obvious and, thus, the connection between oceanography and the U.S. Navy became more and more intimate. Large amounts of funding poured into universities and research institutions to support both military and non-military studies of the oceans.

The four-decade formative period for oceanography as a scientific discipline was, then, a product of the preceding period and at the same time a foundation for the future development. It is doubtful whether without the institutionalization that took place during the period oceanography could become what it was in the following era of great expansion. As Margaret Deacon pointed out, the development of marine sciences could not be continued because of the lack of stable support and institutional basis until the nineteenth century.[45] On the other hand, the advance of the science of the ocean from

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[45] Margaret Deacon, *Scientists and the Sea, 1650-1900: A Study of Marine Science*, 2nd edition (Aldershot, U.K.: Ashgate, 1997). See esp. x-xiv.

the late nineteenth century onward was certainly a continued development. Without a close investigation of the forty years of progress, there would be a missing link in the historical puzzle and the history of twentieth-century oceanography would look discontinuous. Post-World War II development of American oceanography was not a creation of a new scientific field out of nothing but would better be characterized as the enlargement or scaling up of an already existing scientific enterprise.

As late as 1950 American oceanographers still had to ask themselves, “What distinguishes oceanography as a separate scientific discipline requiring a special combination of skills and interests?” They had a clear answer, however, unlike their predecessors half a century ago because oceanography already obtained the status of “a separate scientific discipline” by their times. Oceanographers Vern O. Knudsen, Alfred C. Redfield, Roger Revelle and Robert R. Shrock wrote in 1950:

> Oceanography acquires its unity because it deals with everything taking place in a limited geographical subdivision of the earth—its watery envelope. Problems in oceanography fall rather definitely into two groups, those of geophysics and those of ecology. Their solutions require the various techniques of physics, chemistry, geology, and biology. It is pertinent to ask whether oceanography has its own peculiar disciplines or whether it is merely a collection of those parts of these other sciences which happen to deal with the phenomena of the seas.
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> . . . The conditions in the sea cannot be controlled; moreover, they are characterized by a high degree of complexity, great geographical diversity, and variability with time. The nature of oceanography is determined by these characteristics as well as by the large dimensions involved and by the fact that the fluid nature of the medium results in widespread interrelationships.
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> . . . The principle of dynamic equilibrium may be thought of as a unifying principle of oceanography, in much the same way that the principle that the present is the key to the past underlies and unifies geology. The problems of oceanography require analysis of observed conditions that represent the integration of several processes so as to differentiate and describe the individual processes that are at work. Two

> methods are commonly employed for this purpose: (a) All possible parameters in a given situation are measured and processes are deduced which explain the observed relationships between these parameters in terms of physical, chemical, and biological principles; (b) Comparative studies are made of variations in certain parameters in many situations. These studies can be facilitated in some instances by model experiments in tanks, in which individual processes can be controlled. Statistical correlations are then carried out to obtain empirical relationships, or preferably a simplified theoretical model is constructed and shown to correspond in essential features to the complex reality.
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> Although no individual method or principle of oceanography is unique, it is believed that the combination of principles and methods just described forms a distinct discipline which requires special training.[46]

Oceanographers in the 1950's were dealing with the same object, the oceans, with similar goals, i.e. understanding the natural phenomena of the sea with scientific methods. The difference was that their science was a well-acknowledged scientific discipline and that they knew where to go from where they stood. Upon the institutional and intellectual basis of American oceanography, which was built painstakingly by the preceding generation of American ocean scientists many of whom were their teachers, the new generation of oceanographers was facing new problems and challenges that were demanded of them by the new era.

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[46] Vern O. Knudsen, Alfred C. Redfield, Roger Revelle and Robert R. Shrock, "Education and Training for Oceanographers," *Science*, Vol. 111, No. 2895 (June 23, 1950): 700-703.

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