

**PATRONAGE AND SCIENCE: ROGER REVELLE, THE NAVY, AND
OCEANOGRAPHY AT THE SCRIPPS INSTITUTION**

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Originally published as: Rainger, Ronald. "Patronage and Science: Roger Revelle, the U.S. Navy, and Oceanography at the Scripps Institution." *Earth sciences history : journal of the History of the Earth Sciences Society* 19(1):58-89, 2000. This article is reprinted courtesy of the History of the Sciences Society from *Earth Sciences History*, 2000, 19:58-89.

ABSTRACT

In the years between 1940 and 1955, American oceanography experienced considerable change. Nowhere was that more true than at the Scripps Institution of Oceanography in La Jolla, California. There Roger Revelle (1909-1991) played a major role in transforming a small, seaside laboratory into one of the leading oceanographic centers in the world. This paper explores the impact that World War II had on oceanography and his career. Through an analysis of his activities as a naval officer responsible for promoting oceanography in the navy and wartime civilian laboratories, this article examines his understanding of the relationship between military patronage and scientific research and the impact that this relationship had on disciplinary and institutional developments at Scripps.

In 1947 Harald Sverdrup (1888-1957) and Roger Revelle, two of the leading oceanographers in the United States, made plans for Revelle's return to the Scripps

Institution of Oceanography (SIO). After six years of coordinating and promoting oceanography within the U.S. Navy, Revelle was returning to the center where he had earned his Ph.D. and where, he and Sverdrup hoped, he would now become the institution's new director. Not everyone at SIO, however, supported that plan. Several members of the faculty, led by the ichthyologist Carl Hubbs (1894-1979), opposed Revelle's appointment on personal as well as professional grounds. Pointing out that he was "not a very able top administrator," Hubbs, Francis Shepard (1897-1985), Denis Fox, (1901-1983), Martin Johnson, (1893-1984), and five others also noted that he lacked skills in dealing with personnel. Recognizing Revelle's "scientific ability, . . . broad oceanographic experience," and valuable contacts with the navy, those scientists were willing to place Revelle in charge of work in physical oceanography. Yet their concern for maintaining oceanography as "the balanced ensemble of marine sciences" influenced them to oppose his appointment as the new director.¹

The opposition to Revelle raised several significant issues, among them the perceived connection between Revelle's background in the navy, his interest in physical and geological oceanography, and its implications for the biological sciences. In 1947 the Scripps Institution had just received \$300,000 from the State of California to study the reasons for the decline in the annual catch of the California sardine. That was a tremendous amount of money, and as people associated with ocean sciences realized, it would change the size and scope of activities at Scripps. Many believed that the new director had to have a knowledge of and commitment to marine and fisheries biology. Revelle, according to Hubbs, did not. He obtained an understanding of ecology and marine biology from the work of other people, often with too much enthusiasm and too

little critical assessment. Hubbs also worried what Revelle's ties to the navy might mean for the biological sciences. Revelle himself had suggested as much. Describing the Office of Naval Research (ONR) geophysics program in 1947, he noted that the navy supported work in most fields of oceanography, except some areas of marine biology. If Revelle were appointed director, Hubbs and others feared his ties to the navy, while important for providing financial and material resources, would privilege physical, chemical, and geological oceanography at the expense of biology.²

The issues surrounding Revelle's appointment pertain to a topic of much interest among historians: the relationship between military patronage and scientific research after World War II. Some scholars who have addressed the subject, notably Daniel Kevles and Roger Geiger, have concentrated on the postwar scientific community and emphasized policy issues. Others have shifted the focus of attention away from that community to examine how Cold War politics and the emergence of the national security state have influenced science and technology. Paul Hoch and Sylvan Schweber have used the terms "strategic alliance" and "mutual embrace" to characterize the relationship between the military and scientific communities. Paul Forman's studies examine the impact that national security interests had on the development of quantum electronics, while Stuart Leslie's work explores how political and military objectives have become embedded in technological artifacts, laboratories, disciplines, and geographies. How such factors shaped research at RAND is the subject of a recent study by David Hounshell.³

This article examines one aspect of that subject, namely whether patronage influenced developments in mid-twentieth-century American oceanography.

Concentrating on developments at SIO during and after World War II, the paper explores changing patterns of patronage, the increasing importance of physical, chemical, and geological oceanography, and its consequences for biological work at that institution. Revelle played a major role in American oceanography in the 1940s and 50s; this article devotes considerable attention to his activities and their impact on disciplinary and institutional developments at Scripps.

SCRIPPS' OCEANOGRAPHY BEFORE WORLD WAR II

In the early 1930s, when Roger Revelle began graduate work at Scripps, oceanography was all but unknown to the American scientific community. The two major oceanographic centers, SIO and the Woods Hole Oceanographic Institution (WHOI), were small, isolated laboratories located on opposite ends of the continent. Each had staffs of no more than fifteen people, one boat, and minimal physical facilities.⁴

Both institutions relied on multiple sources of support. Private philanthropy, a major source of funds for most fields of American science in that period, was crucial for oceanography. The Rockefeller Foundation was the principal patron of Woods Hole, while SIO, a division of the University of California, received almost half its support from the Scripps family. In the late 1930s, when the family's fortune suffered with the depression, SIO began to diversify its bases of support. As the university increased its allocation, administrators emphasized that Scripps' scientists should seek assistance from other interests. In addition to George McEwen (1882-1972), whose work on weather forecasting received support from utility companies, Sverdrup signed contracts with state and federal agencies for research in relation to fisheries. Revelle, whose studies on ocean

bottom sediments offered insights into the process of petroleum formation, received grants from the American Association of Petroleum Geologists and attracted the attention of oil companies.⁵ Neither institution received much direct federal support. Scripps's first director, Thomas Wayland Vaughan (1879-1952), established agreements with several government agencies to provide Scripps with temperature, salinity, and dynamic sounding data from the Pacific and Caribbean. By the mid 1930s the Hydrographic Office (HO) was allowing Scripps's scientists, including Revelle, to collect data onboard its ships. But besides Sverdrup's work with the Fish and Wildlife Service, the only other direct federal support came from the navy, which sponsored research to develop anti-fouling methods for protection of ships' hulls.⁶

Oceanography's practitioners defined the field broadly. Vaughan and Henry Bryant Bigelow (1879-1967), the director of WHOI, did not consider oceanography a specific discipline. Rather they considered it the study of a particular place, the oceans, and oceanographers employed the knowledge, techniques, and methods from geology, biology, physics, and chemistry to examine the subject.⁷ At SIO Vaughan, a geologist, initiated studies in geological oceanography, particularly analyses of bottom sediments and submarine topography. The faculty included McEwen, a physical oceanographer, and Eric Moberg (1891-1963), a graduate student just completing his work in chemical oceanography. SIO also inherited staff members from its predecessor organization: William Emerson Ritter's (1856-1944) Scripps Institution for Biological Research. C. O. Easterly (1879-1928), a zooplankton specialist who worked at Scripps each summer, died in 1926, but W. E. Allen (1873-1947) remained actively involved in teaching and

research on phytoplankton. Many of the graduate students, men as well as women, studied marine biology.⁸

Despite Vaughan's efforts to promote a broad program, problems arose by the end of the decade, particularly with those working in biology. One source of the controversy was Francis B. Sumner (1874-1945), a faculty member whose work on the genetics of deer mice had nothing to do with oceanography. For years Vaughan had tried to transfer Sumner to Berkeley or, failing that, to have Sumner return to his earlier work on fishes. In 1929 difficulties between Vaughan and Sumner came out into the open.⁹ In that same year Vaughan became involved in an acrimonious dispute with Allen. Vaughan's work on coral reefs emphasized an ecological approach and included physiological and chemical experiments. He also stressed the importance of experimentation in marine biochemistry and bacteriology. In 1929 Vaughan proposed to use \$40,000 given by the Rockefeller Foundation to build a new laboratory for research in physiology and marine biochemistry, and hoped to place one of his graduate students in charge of that laboratory.¹⁰ That effort angered Allen, whose analyses of phytoplankton represented a different kind of research. Vaughan conceded that Allen's work had resulted in the accumulation of "a tremendous amount information on the variations in kind and quantity of diatoms and dinoflagellates," but he also claimed that "attempts to interpret the significance of the variations . . . have not yielded important results." Allen defended his research, and with support from others charged that Vaughan had made no attempt to define or coordinate SIO's work in oceanography; instead there existed only "dissociated activities or simultaneous investigations along several unrelated lines." He especially

criticized Vaughan for not making use of the institution's boat and for shifting SIO's work from outdoors to indoors, from sea to land.¹¹

That controversy, which lasted until Vaughan's retirement in 1936, helped solidify his views about oceanography. He continued to support work in all fields, and in 1931-32 hired Denis Fox, a marine biochemist, and Claude Zobell (1904-1989), a specialist in marine microbiology. Increasingly, however, he emphasized the need for Scripps to incorporate the new dynamical oceanography coming out of Norway. Vaughan did not fully understand that work, nor was he able to convince the Scripps family or other patrons to purchase a sea-going vessel that would enable Scripps scientists to conduct such research. Nevertheless, he pressed administrators at the university to hire the one individual who could lead Scripps in those directions: Harald Sverdrup.¹²

Sverdrup came to Scripps in the summer of 1936 with a background in physical oceanography. In Norway and Germany he had studied physics under Vilhelm Bjerknes (1862-1951), a founder of modern meteorology. Sverdrup's work included investigations on the air/sea boundary, the impact of winds on the Earth's Coriolis force, and heat and energy transfer between atmosphere and ocean. By the 1920s he and Bjerknes were describing waves, circulation, and turbulence in relation to physical and meteorological principles, and in quantitative terms.¹³

Sverdrup first sought to promote that work at Scripps through a project with the California Fish and Game Commission. Scientists at that agency, concerned about fluctuations in the annual catch of sardines, contracted with SIO to do drift bottle investigations that, by providing information about currents, could identify conditions for spawning. Working onboard the commission's ship, the *Bluefin*, Sverdrup and Richard

H. Fleming (1909-1990) monitored oceanographic stations that yielded valuable information on the temperature, salinity, and oxygen content of the waters. That work led them to identify two distinct water masses. More important, they presented a new interpretation of the process of upwelling. Scientists had known of upwelling for some time, but described it as a vertical motion whereby subsurface waters replaced surface waters and yielded changes in nutrients, chemicals, and minerals. Sverdrup and Fleming now demonstrated that it was a more complex phenomenon. Between March and May 1937 they noted changes in water masses that they correlated with a change in wind direction and velocity. Wind produced, tangential stresses had produced a boundary region where, temporarily, upwelling occurred. In short, Sverdrup and Fleming's discussion of upwelling constituted a dynamical description of a complex phenomenon.¹⁴

For Sverdrup that work had more than conceptual consequences. In his view, analysis of currents and upwelling off the coast of California provided an opportunity for a coherent research program. He now suggested that a series of expeditions, based on the Fish and Game Commission model, would bring together the diverse scientists at Scripps and take them to sea. According to Sverdrup, the study of water masses, mixing, and upwelling would require analysis of the chemistry of seawater, monitoring of sea level, and correlation of oceanographic with meteorological data. An understanding of currents and eddies required knowledge of ocean bottom sediments and topography, the kind of work done by Reville and Francis Shepard. The 1937 expeditions highlighted the role that physical oceanography could play in incorporating the other sciences of the sea. They also set the stage for a new and ambitious undertaking: the SIO expeditions to the Gulf of California in 1939-40.¹⁵

Those expeditions promoted work in marine geology and biology within the context of physical oceanography. Sverdrup's interpretation of upwelling caught the attention of fisheries biologists, and in 1940-41 he negotiated contracts with the Fish and Wildlife Service. The Gulf of California expeditions enabled two new faculty members, Martin Johnson and Marston Sargent (1906-1986), to conduct investigations on marine vertebrates and plant physiology. That program also had benefits for W. E. Allen. Despite Vaughan's efforts to have Allen fired, he remained on the faculty through 1938. Convinced that Allen's phytoplankton studies offered insights into upwelling, Sverdrup prevailed upon the university administration to allow Allen to continue his research. In contrast to his early studies that considered phytoplankton distribution in relation to light, salinity, and temperature, Allen and Sverdrup now established a positive correlation between upwelling and diatom abundance. Sverdrup's work had done more than revive a career; it gave new meaning and significance to Allen's biological data.¹⁶

Sverdrup's influence and the growing importance of physical oceanography were most evident in *The Oceans*, the massive text he published with Johnson and Fleming in 1942. Throughout the authors sought to apply the principles of physics as the means for understanding ocean currents, waves, tides, the movement of ocean bottom sediments, and the chemistry of seawater. Johnson's chapters examined marine plants and animals in relation to light, temperature, ocean currents, and other physical-chemical parameters, but with the objective of offering an ecological interpretation of the distribution and interrelationships of marine organisms. A highly sophisticated study that stressed the centrality of the physical sciences, *The Oceans* also provided a meaningful framework and foundation for marine biological research.¹⁷

THE NAVY, THE NDRC, AND PHYSICAL OCEANOGRAPHY DURING WORLD WAR II

While Sverdrup was laying the groundwork for a research program at Scripps, physical oceanography received a boost from a new and different source. In the late 1930s the threat posed by German submarines made military and political leaders increasingly anxious about the nation's ability to wage subsurface warfare. German submarine activities during World War I had led the Naval Consulting Board and the National Research Council to enlist scientists and engineers for work on subsurface warfare. After that war only the Naval Research Laboratory continued activities along those lines. A small team of scientists and engineers working with Harvey C. Hayes (1878-1968) developed a workable sonar system which the navy was soon installing on ships. Continued detection problems, particularly on sonar tests conducted in Guantanamo Bay, Cuba eventually led the navy to contact oceanographers at Woods Hole. Studies by Columbus O'Donnell Iselin (1904-1971) demonstrated that physical factors, primarily temperature and pressure, affected sound transmission in seawater. By 1938 WHOI oceanographers had developed an instrument, the bathythermograph (BT), capable of recording temperature and pressure at depth and thus providing a continuous record of the effect of seawater on sound waves. Underwater sound, a subject that had been ignored by oceanographers, offered a means for improving sonar performance and submarine detection and attracted the attention of a new and powerful patron.¹⁸

The navy had an obvious interest in that subject, but so too did Iselin and other civilian scientists anxious to obtain increased opportunities and support for science in the event of war. By late 1940 Iselin was not only producing BTs and training ensigns for

the navy; he had also negotiated a contract for work in underwater sound through the new National Defense Research Committee (NDRC). In addition, he suggested to friend and neighbor Frank B. Jewett (1879-1949) that problems with navy bureaucracy and ongoing questions about the quality of the navy's sonar work warranted investigation. The resulting National Academy of Sciences study, dubbed the Colpitts Report, was critical of the navy's program. By the spring of 1941 the navy and the NDRC had established a large-scale cooperative project in subsurface warfare. In addition to its contract with Woods Hole, the NDRC established a special studies group devoted to sonar analysis. Harvard University became the site for an underwater sound laboratory, and two new laboratories were created: the Columbia University Division of War Research (CUDWR) and the University of California Division of War Research (UCDWR). Both had affiliations with their respective academic institutions. Both were also located on military installations and had close ties to the navy: the CUDWR at Fort Trumbull, New London, Connecticut, in close proximity to the Navy Submarine Base; and UCDWR on the grounds of the Navy Radio and Sound Laboratory (NRSL) in Point Loma, California. Based on careful negotiations, the civilian laboratories would function as centers for research on underwater sound as well as design and construction of underwater sound equipment, while the navy had responsibility for testing and development of instruments and weapons.¹⁹

At UCDWR and elsewhere oceanographers entered into a new and different world, one that emphasized the priorities associated with subsurface warfare. The need to understand the ocean environment and to design, test, and manufacture instruments and weapons for fighting a war in that environment, required a wide range of specialists.

As part of an extensive system for building and testing new equipment for detecting and evading submarines, torpedoes, and other underwater weapons, scientists now worked with engineers, contractors, and navy officers to fulfill requisitions, meet deadlines, and assist with the mass production of instruments. Those activities required learning navy rules, guidelines, and language, and becoming well acquainted with the operations of navy ships and submarines. Oceanographers were now working in a new field of inquiry, with new instruments, and for a patron whose interests emphasized operational objectives.²⁰

Within that culture work in underwater sound became a top priority. In early 1941 Iselin and Maurice Ewing (1906-1974) completed a report entitled "Sound Transmission in Sea Water." The study was designed to convince scientists and navy leaders that physical factors influenced underwater acoustics. Based on experiments conducted at Guantanamo Bay and Key West, Florida, they calculated and diagrammed the paths of sound rays under varying conditions. Emphasizing that sound waves were generally refracted in sea water, the authors indicated how temperature, pressure, and, to a lesser extent, salinity affected the horizontal and vertical velocity of sound. Information concerning how physical factors yielded positive or negative vertical velocity gradients had clear implications for echo ranging. Calling for additional studies on the behavior of sound under different conditions and in different locations, Iselin and Ewing stressed that scientific investigations would improve equipment performance.²¹

Iselin's efforts were crucial in advancing work on underwater sound. Demonstrating that the behavior of underwater sound varied by location, time of day, and season of the year, he was instrumental in convincing the navy to support a program of

research. While Woods Hole took the lead in underwater sound, similar projects were established elsewhere. With the creation of UCDWR in the summer of 1941 several SIO scientists, including Fleming, Shepard, and Johnson, transferred to Point Loma, fifteen miles away. While that laboratory included projects on cavitation, attenuation, and underwater noise, UCDWR oceanographers, like their counterparts at WHOI, soon began receiving BT slides collected by navy vessels worldwide. When Iselin called for the construction of sound ranging (sonar) charts to aid ships' officers and sonar operators in strategically important locations, scientists at both institutions responded. Iselin's statement that "the local range of horizontal signals [from echo ranging equipment] will soon be predictable in a routine way from BT records" stimulated much additional work.²²

Revelle's early work had been in geological oceanography, but he too became involved in studies of underwater sound. In the spring of 1940, Revelle, an officer in the Naval Reserve, received a request to spend a week with the Fiftieth Destroyer Division in Point Loma, California. The commanding officer of that unit, Captain A. D. Burhans, was conducting tests with underwater sound equipment and wanted Revelle to assist with interpreting how oceanographic conditions affected sonar performance. Following that exercise, Revelle returned to his work in marine geology but also continued to participate in sonar tests. In May 1941 he submitted a report, "Surface Temperature Gradients and Predicted Sound Ranges in the North Pacific Ocean," to the navy.²³ Called into active duty at the NRSL the following month, he continued to work closely with Fleming and Sverdrup on light scattering, micro-temperature of sea water, and other topics pertaining

to underwater sound. He and Fleming also developed a slide rule for calculating sound ray paths from BT data.²⁴

Despite auspicious beginnings, including a proposal for a cooperative program in oceanography among NRSL, SIO, and UCDWR, difficulties soon arose for Revelle and other oceanographers on the west coast. UCDWR shared facilities with the military on the grounds of the NRSL, and as the civilian laboratory expanded so too did disputes over space, facilities, and other resources. The NRSL's commanding officer, Captain W. J. Ruble, had worked on underwater sound during World War I and viewed it as a navy, not a civilian, activity. By October 1941 he and the UCDWR director, Vern O. Knudsen (1893-1974), were at loggerheads over the use of ships, use of sonar equipment, and access to waters and marine facilities. That dispute, followed by Ruble's later controversy with Knudsen's successor, Gaylord P. Harnwell (1903 -1982), created serious obstacles for cooperative work in oceanography.²⁵ At the same time additional troubles emerged at Scripps. Sverdrup, despite his standing in the scientific world, was a Norwegian immigrant who, among other things, had worked in Germany during World War I. In February 1942 the Office of Naval Intelligence denied him and Walter Munk (b.1917), another Scripps oceanographer, security clearance. Although Sverdrup had clearance from the Army Air Force to teach and do research in meteorology, he now could not participate on projects in underwater sound. Handicapped by obstacles that now prevented cooperation with scientists at SIO and UCDWR, Revelle began requesting transfers to other navy agencies.²⁶

Despite those problems Revelle remained involved in work on underwater sound. In 1942 he participated in NRSL surveys of strategic harbors that included investigations

of how bottom topography, composition, and currents affected echo ranging. He also participated in studies of wakes.²⁷ Those investigations brought him some recognition, but more important was the navy's increasing demand for oceanographic information. The continued expansion of the BT program, coupled with increasing requests for oceanic data from the Bureau of Ordnance, the Naval Ordnance Laboratory, and other agencies, indicated the need to appoint a navy officer to coordinate that work. Revelle received the appointment, and in late 1942 was put in charge of oceanographic projects in the HO and the Navy Bureau of Ships. Those appointments provided him with responsibility for many projects, and Revelle moved to the center of activity in oceanographic work related to subsurface warfare.²⁸

The work in those organizations emphasized physical, chemical, and geological oceanography. Appointed to head up a small sonar design section in the Bureau of Ships, Revelle had responsibility for development and production of BTs. He also served as the navy liaison to NDRC projects on underwater sound. Revelle had little to do with the actual research, experimentation, and testing that went into developing predictive models that indicated how oceanographic conditions would affect sonar performance, but he participated with NDRC scientists in analyzing and assessing those models.²⁹ His office published and distributed throughout the navy BT prediction manuals that described how a knowledge of conditions would influence tactical operations, including maximum range of prediction (the greatest distance at which a submarine can be detected), assured range (the maximum range on a submarine at the most unfavorable depth for detection), and the maximum echo range on a submarine at the surface (periscope depth range) or below the surface (evasive range). In 1942-43 new

discoveries about the thermocline and layer effect, along with the development of the submarine BT, opened up a new dimension of submarine warfare: knowing under what conditions submarines could hide from enemy sonar. Revelle took an active part in testing and evaluating the submarine BT and developing predictive models for pro-submarine warfare.³⁰

To some extent, the work done on underwater sound involved biological studies. At the NRSL, the harbor protection surveys in which Revelle participated included listening experiments conducted by UCDWR scientists and engineers. Investigations by F. Alton Everest (b. 1909), T. F. O'Neil, and R. W. Young indicated that the underwater environment was a noisy place indeed. Further studies by Martin Johnson indicated that sounds produced by marine organisms, particularly snapping shrimp, could affect the ability to detect and evade submarines. Efforts to identify the range and distribution of snapping shrimp and other sound-producing organisms became an important component of the program in subsurface warfare, and Johnson carried out studies in the Caribbean and South Pacific. He conducted those investigations in cooperation with the navy, and Revelle was well aware of the significance of Johnson's work. Still his research as well as fleet reports of sounds made by whales and other marine animals, were important only insofar as they pertained to underwater sound transmission.³¹

The Hydrographic Office emphasized other aspects of physical and geological oceanography. Underwater sound transmission required an understanding of how sound was absorbed, reflected, or reverberated by different bottom sediments and conditions. Bottom sediment charts, as Iselin noted, were valuable

for range predictions and . . . are therefore an important part of the general tactical considerations involved in the spacing of vessels and the operation of sonar equipment so as to obtain maximum efficiency. They are equally important to submariners in the latter respect and can also be used in choosing favorable operating areas.

Working with Shepard at UCDWR and H. C. Stetson (1900-1955) at WHOI, Revelle coordinated efforts to collect information, conduct sound transmission experiments over different bottoms, and develop standardized bottom sediment charts that would be distributed throughout the navy.³²

A knowledge of ocean bottom sediments had additional significance for the navy. In 1942, when the Navy Coordinator of Research and Development requested the bureaus to provide information on the relevance of oceanic data to naval operations, the Bureau of Ordnance and Naval Ordnance Laboratory stressed the need for data to aid in detecting mines in shallow waters. Their concerns had an impact on the creation of the FM sonar system at UCDWR. But those agencies also pressed for additional initiatives on ocean bottoms. Writing to Iselin in June 1943, Revelle pointed out that the navy wanted to know how mines dropped from planes or ships penetrated different ocean bottoms. How underwater currents and wave amplitude on ocean bottoms affected the movement of underwater mines, or how the color of bottom sediments could be employed to camouflage mines, were important to ordnance organizations.³³ The war in the Pacific intensified those needs, and throughout 1944 and 1945 Revelle pushed scientists at WHOI, UCDWR, and SIO to accelerate their work on ocean bottoms.³⁴

Revelle's oceanographic unit was also involved in amphibious warfare. Planning and executing beach landings in the Atlantic and Pacific required extensive, detailed data on underwater, inshore, and coastal conditions in a wide variety of circumstances.

Revelle's office was called upon to provide information on those topics, but he was also able to redefine and shape the ways in which oceanography could contribute to the navy's objectives. In the process he expanded the role played by Sverdrup and others at Scripps.

Through his position in the Hydrographic Office, Revelle received an appointment as the navy representative to a new oceanographic sub-committee of the Joint Chiefs of Staff Committee on Meteorology. As the United States took the offensive in the war, the Joint Chiefs expressed concern about developing methods for wave and surf forecasting in support of amphibious landings. Responsibility for that work lay with the Army Air Force (AAF), which maintained a small unit on the grounds of the Scripps Institution. Sverdrup provided that organization with basic isothermal information, but his security status did not enable him to participate in efforts to develop a system of wave forecasting. In early 1943 when the AAF unit presented results of its work to the Joint Meteorology Committee, Revelle expressed skepticism. Pointing out discrepancies between predictions developed by the AAF and by British scientists, he questioned the AAF's findings. He also challenged the AAF's reliance on empirical methods and suggested that Sverdrup, the world's leading expert on winds, waves, and currents, could develop a more accurate system. When McEwen, the SIO scientist who had assisted the AAF, was denied security clearance in the spring of 1943, pressure increased for clearance for Sverdrup. By late 1943 Sverdrup and Munk had developed a new theoretical model for forecasting sea, swell, and surf, one that navy officers claimed was

superior to the AAF system. In addition to establishing a program at Scripps under Sverdrup's direction, the Joint Chiefs accepted a proposal from Revelle to transfer all work on waves and currents from the AAF to the navy. Revelle was not solely responsible for that transfer, or for Sverdrup's security clearance, but he had played a pivotal role that now enabled Scripps's scientists to employ their expertise in physical oceanography for the purposes of amphibious warfare.³⁵

Revelle also had responsibility for another related activity: collecting data on beaches, shorelines, and coasts that would aid in amphibious operations. At Scripps, Sverdrup and Munk worked with engineers and naval forces to test which locations, which kinds of ships, boats, and amphibious vehicles, and which surf conditions were best for making landings and establishing beachheads. Revelle and the HO looked to scientists at UCDWR and WHOI to supply information on slope, composition, erosion, and "trafficability" of beaches and inshore environments. Operational demands also called for extensive information about underwater formations, and HO ships routinely conducted dredgings and soundings of Pacific islands and atolls. As Revelle later stated: "It has become apparent that the society which knows the most about its environment, and how to turn it to account, is going to be the more likely to win the next war." Military objectives necessitated more than detailed geodetic and hydrographic data; they required the development of predictive models for forecasting how amphibious landings could be made anytime, anywhere. Those objectives reinforced the emphasis on the physical sciences.³⁶

The HO also expanded opportunities for oceanographers working on subsurface warfare. For years that agency had produced a publication, *The Sailing Directions*, that

provided information to mariners worldwide. By 1943, as the Pacific theatre became increasingly important so too did anti-submarine warfare. Revelle proposed that the HO begin issuing a new publication: the *Submarine Supplements to the Sailing Directions*. Those manuals would supply submariners with data on temperature and pressure, bottom sediments, and bathymetry. Because of Scripps's location and its outstanding collection of Japanese oceanographic literature, Sverdrup, in cooperation with the oceanographic division of UCDWR, helped produce all the submarine supplements for the Pacific.³⁷

By virtue of his role within the navy, Revelle had become a major player in wartime oceanography. His positions in the Hydrographic Office and the Bureau of Ships brought him into close contact with leading NDRC scientists. Some of those figures - Iselin, Fleming, and Sverdrup - were acquaintances from earlier years, but he now became well connected with prominent physicists and geophysicists throughout the country. Equally important were his contacts within the military. Working closely with top officials in the navy and other military organizations, he became well aware of that service's growing interest in and commitment to oceanography. Serving as a point of contact within the navy for civilian scientists on the one hand, he worked to define and expand the navy's commitment to oceanography on the other hand. Seeking to convince navy leaders of the capabilities of oceanographers, he became a strong proponent of the navy's interests and objectives to the members of the civilian scientific community. In contrast to Iselin and Sverdrup, both of whom expressed skepticism about government patronage of oceanography after the war, Revelle embraced and promoted the possibilities of ongoing navy sponsorship of the science.³⁸

Revelle had also gained an understanding of the navy's priorities. Well aware of the navy's commitment to developing new instruments and weapons, he also recognized that agency's need to control the war fighting environment, be it on the land, on the sea, or under the sea. The need to control vital sea lanes required not only sonar systems but an understanding of the physics and chemistry of surface and subsurface layers. The need to establish and maintain controls of islands, atolls, and coastlines required considerable geodetic, hydrographic, and bathymetric information. The war years provided Revelle with an insider's understanding of the navy's interests and objectives, including an understanding of which fields of oceanography it deemed important.

REVELLE, THE NAVY, AND POSTWAR OCEANOGRAPHY

By the end of the war, leaders in the Bureau of Ships, the Bureau of Ordnance, the Hydrographic Office, and the Amphibious Forces were praising the ways in which oceanographic studies had enhanced their activities. Navy and civilian science administrators now sought to devise means for retaining scientists and engineers after the war. From the navy's perspective, scientists were needed to evaluate systems like FM sonar and deep submergence submarines that came into use late in the war. Their knowledge of the conditions under which such systems could best be deployed was considered indispensable. Scientists and engineers could also assess the threat of new weapons, the snorkel submarine and underwater guided missiles, and develop countermeasures.³⁹ Geopolitical interests were also at stake. The navy needed to know about underwater sound conditions to ensure that the United States was well prepared for detecting and hiding submarines. Beach and harbor protection were equally important.

Those who spoke for navy bureaus emphasized technological needs, yet the ways in which scientific information could aid in the nation's economic, political, and military objectives were also important.⁴⁰

Revelle took part in the effort to meet those objectives. In September 1944, when Vannevar Bush (1890-1974) announced the forthcoming termination of the Office of Scientific Research and Development, the navy and NDRC began negotiations for the postwar continuation of navy oceanographic activities. Between October 1944 and January 1945, the NDRC and Bureau of Ships, often represented by Revelle, held numerous meetings to determine which navy wartime projects would be continued, under whose auspices, and in what locations. Some of the most difficult decisions concerned UCDWR, since that laboratory housed such a wide range of activities. Civilian oceanographers and navy officers wanted to continue BT processing and analysis, studies of waves and currents, and the work on bottom sediments. Revelle's offices had supervised those projects during the war, but negotiations led to agreements whereby they would be turned over to civilian laboratories.⁴¹ UCDWR also had responsibility for work on underwater acoustics that was highly classified, required access to navy testing and production facilities, and could not readily be transferred to SIO. Some projects went to navy laboratories, but in late 1944 Revelle proposed the creation of a new entity to continue sonar work: the Marine Physical Laboratory (MPL) which would be funded by the Bureau of Ships but run by the University of California.⁴²

More important than the institutional arrangements was the need to establish a working relationship that would appeal to scientists and the military. Following the four year conflict, few scientists wanted to remain involved in war related work. Leading

oceanographers agreed that the HO should become the center for naval oceanography, but maintained that scientists should be "more or less remote from the immediate routine of the Navy" and only conduct "broad fundamental research required to aid in obtaining results of ultimate practical significance." Several expressed concerns about secrecy, ability to publish, and the increased costs and bureaucracy that would accompany military support.⁴³ But by 1945 those scientists also realized that oceanography could not do without the navy. The navy offered greater financial support than any other patron; it also maintained control of the ships and subs, BTs, sonar systems, and underwater cameras that had become necessary for deep sea research. Oceanographers, in short, needed the navy as much as the navy needed oceanographers.

What emerged from negotiations between civilian oceanographers and navy officials was an understanding designed to meet the needs of both communities. In early 1945 a small contingent of scientists, eager to obtain support for the study of problems that they considered significant, pointed out how work in virtually all areas of physical, chemical, and geological oceanography had potential military applications. According to Iselin, Fleming, Sverdup, and Lyman Spitzer (1914-1997), studies of ocean bottoms, surface layers, beach processes, and other topics were both conceptually meaningful to oceanographers and operationally useful to the navy. Aware that navy operational and technological objectives were paramount, those scientists also understood that the military required their services. By identifying and defining the ways in which oceanographic research could serve the navy, those scientists were embedding their interests within the context of the military's objectives. The consensus defined in 1945

would enable oceanographers to receive support for fundamental research, but also required that they participate in and contribute to military work.⁴⁴

Revelle, who had a hand in hammering out that understanding, also took the lead in promoting it within the navy. He did so first by arranging for the Hydrographic Office to turn over BT processing and analysis to SIO. To replace the former OSRD agreements, he helped design Bureau of Ships contracts.⁴⁵ Most important, he sought to implement that understanding through navy sponsored expeditions. Revelle remained in the navy after the war, and, as described elsewhere, organized oceanographers, geophysicists, and other scientists to take part in Operation Crossroads, the Pacific atomic bomb tests held at Bikini Atoll in 1946. He also conceived and directed a follow-up expedition, the Bikini Scientific Resurvey, the next year. While work on Crossroads served to provide scientific assessments of a weapons test, the Bikini Resurvey offered greater opportunities for research. Deep drillings into the core of the atoll emphasized the resurvey's effort to solve the longstanding problem of coral reef formation. Other scientists conducted seismic refraction tests, wave analyses, and studies of the reef, fishes, and other marine organisms in the area. The principal purpose of the biological studies, however, was to assess diffusion of radioactive material in the waters. Work in physical, chemical, and geological oceanography was among the primary activities of the resurvey, but did not reflect just the scientists' interests; it also embodied navy priorities. Seismic refraction studies yielded valuable information about subsurface geology and the underwater structure of atolls; they also tested underwater sound equipment, employed explosives as countermeasures against mines, and used sound transmission to detect underwater guided missiles or atomic explosions. Analyses of sediments, gradients, and

movements along beaches, reefs, and atolls were crucial to the navy for planning and conducting amphibious operations. Shallow and deep water soundings, undertaken by scientists to elucidate the relationship between underwater volcanoes and atolls, also enhanced the means for determining the position of deep submergence submarines. As Revelle noted in 1947, postwar expeditions served two main purposes: discovering new scientific principles, and enhancing the ability to wage war. Claiming that "[I]n some cases these two purposes are entirely inseparable," Revelle effectively identified the relationship between navy patronage and physical, chemical, and geological oceanography.⁴⁶

REVELLE, OCEANOGRAPHY AND THE SCRIPPS INSTITUTION

Those emphases would continue to influence Revelle's views when he returned to La Jolla early in 1948. Although one of Revelle's assignments as the new associate director was to take charge of the state funded sardine project (see below), he fully understood the importance of federal patronage for oceanography and remained actively involved with civilian and military agencies in Washington, D.C. Throughout the late 1940s and early 1950s he participated on the Pacific Science Board, a section of the National Research Council that promoted investigations by scientists and social scientists in the western Pacific. An active member of the NRC Committee on Amphibious Operations, he chaired a project devoted to improving underwater equipment and training swimmers for harbor protection work.⁴⁷ On the military side, Revelle served on the Research and Development Board, a committee that assessed new scientific and technological advancements for the Joint Chiefs of Staff. He also increased contracts

between Scripps and military patrons. During World War II HO activities in amphibious warfare included work with the Beach Erosion Board, a division of the Army Corps of Engineers. In 1949 that agency contracted with SIO for studies of beach sediments, gradients, and shoreline processes. Revelle's interest in the air/sea boundary led to contracts with the Air Force Cambridge Research Laboratory, and in 1952 he convinced S. Q. Duntley (1911-1999), a specialist on light penetration in the sea, to transfer his visibility laboratory, funded largely by the Air Force, from MIT to Point Loma.⁴⁸

But the navy remained the principal patron of oceanography, and Revelle worked on several fronts to increase navy support for SIO. Particularly important were his ties to the Office of Naval Research (ONR). From 1946 until early 1948, Revelle served as the first head of the geophysics branch of ONR. There he had a hand in granting SIO contracts for work on waves, currents, general oceanography, and oceanographic education. Revelle also helped provide Scripps with its first deep-sea vessels as well as BTs, fathometers, and other equipment. Before leaving ONR Revelle made sure that his successor, Gordon Lill (1918-1996), had a clear understanding of the objectives of the geophysics program. By the end of the decade ONR, the Bureau of Ships, and the Hydrographic Office were providing SIO with over \$900,000 annually.⁴⁹

Revelle also established closer ties with nearby navy facilities. Negotiations in 1944-45 had resulted in the transfer of many UCDWR projects to the NRSL and MPL, both located at Point Loma. Bureau of Ships contracts with MPL included support for experiments on SOFAR, underwater channels in which sound could travel uninterrupted for thousands of miles. Identification of SOFAR channels was important for anti-submarine warfare and detection of underwater guided missiles and atomic explosions.

SOFAR contracts called for assistance from SIO, but because Sverdrup did not have clearance for work on underwater sound, interaction between the two institutions was limited. That changed in 1948, in part because Sverdrup appointed Carl Eckart (1902-1973), director of the MPL, his successor at Scripps. But Revelle also made relations between MPL and SIO a priority. While still in Washington, he informed Sverdrup that "a merger of the Marine Physical Laboratory with the Scripps Institution would be desirable and fruitful." One of his first acts as associate director was to examine the relationship between SIO, MPL, and the NRSL, recently redesignated the Navy Electronics Laboratory (NEL). Negotiations with navy officials, including Rawson Bennett (1905-1967), Revelle's former boss at the Bureau of Ships and the new director of NEL, led that laboratory to provide office and laboratory space for SIO at Point Loma. Revelle moved several physical oceanographers as well as Fish and Wildlife biologists to what now became called the Scripps Annex. With a fleet of three ships, Scripps had outgrown the dock at the San Diego Yacht Club, and through Revelle's efforts SIO also acquired a new marine facility at Point Loma.⁵⁰

Revelle's interest in navy support had consequences for oceanographic education at Scripps. Oceanography had played an important role in World War II, but it remained a small field with few professional job opportunities. The stimulus for growth came from the navy which needed trained oceanographers to help combat underwater threats and maintain an American military presence worldwide. Throughout the late 1940s, navy officers and enlisted men constituted a significant percentage of the students taking classes at SIO. In addition, ONR grants included funding for oceanographic training and education. The navy placed a high priority on work in those fields, and beginning in

1948-49 the names of several MPL and NEL scientists appeared on the SIO faculty register. There also occurred a change in educational emphasis at Scripps. During the 1930s and 1940s, the majority of graduate students completing Ph.D.s at Scripps had worked in the biological sciences. By mid century the balance began to shift, and during the 1950s forty-nine graduate students received doctorates in oceanography as compared to eight in zoology and microbiology.⁵¹ The change stemmed in part from alterations in the SIO curriculum. Traditionally, the Scripps catalogue listed research courses for each individual branch of oceanography. But in 1949 Eckart and Revelle succeeded in changing the curriculum to list only one research course. One result was that work in marine biochemistry and microbiology would "not be supported by the Department of Oceanography but by those departments that would normally support biochemical work on the UCLA campus." In Eckart's words:

It is felt that the Department of Oceanography should confine itself to the ocean as its object of study. Undoubtedly the animals and plants living in the ocean form a part of this object. On the other hand, not all aspects of the biology of invertebrates, or of microbiology, can properly be classed as oceanography. At the present time it is one of the responsibilities of the Scripps Institution, as one of the few places where instruction in oceanography can be obtained, to define the limits of the science of oceanography, and to stimulate the formation of a unified profession.⁵²

Eckart and Revelle's attempt favored physical, chemical, and geological oceanography, and while students interested in biochemistry and microbiology could do "interdepartmental" work, that entailed curricular and logistical difficulties. In the late

1940s the most exciting developments were occurring in physics and geophysics, and that accounted for some of the increase in students. But those were also the fields most in congruence with the navy's interests, and by 1950 most central to the Scripps curriculum.

Revelle also looked to the navy to support expeditions. Prior to 1941, Scripps's scientists had done no deep-sea research. The war changed all that, and scientists worked side by side with sailors and officers on ships and submarines throughout the world. Those activities took oceanographers out to sea and under the sea. Expeditions conducted in the last years of the war yielded significant new information about underwater geological formations in the western Pacific. Crossroads and the Bikini Resurvey raised greater expectations about new oceanographic and geophysical findings. Revelle, excited by that work as well as Maurice Ewing's studies of the mid-Atlantic ridge, was eager to take advantage of scientific opportunities and navy patronage. In the fall of 1949 he began laying the groundwork for another trip to the Marshall Islands: the Mid Pacific Expedition.⁵³

From the outset Revelle viewed Midpac as a joint navy-university endeavor. Turning first to ONR, it was only after that agency pledged \$15,000 toward the expedition that Revelle approached the University of California for support.⁵⁴ Although the expedition represented the university, and Scripps scientists would work onboard their own new vessel, *Horizon*, Revelle understood that any work in the Trust Territories required security clearance and military support. He also knew that the navy would play an active role in the venture. Revelle had in mind an expedition that included geophysical experiments on and beneath the sea floor and required a wide array of instruments and personnel. With help from former colleagues at the Bureau of Ships,

NEL supplied a ship equipped with good echo sounding and oceanographic gear. The navy also provided fathometers, side scanning sonar, and amplifying and recording instruments for measuring the intensity of sound scattering. Many on the SIO staff would take part in Midpac, but Revelle relied on NEL for additional scientific assistance. Since the end of the war that laboratory had maintained oceanography and sea floor studies programs headed by trained geophysicists. At Revelle's request the NEL assigned Robert Dietz (1914-1995), Edwin Hamilton (1914-1998), and H.W. Menard (1920-1986) to Midpac. Russell Raitt (1907-1995), the MPL's SOFAR expert, also joined the expedition.⁵⁵

As Revelle had anticipated, Midpac yielded notable scientific discoveries. The scientists onboard were "constantly astonished at what the instruments were showing. So numerous were the discoveries that our second great expedition, Capricorn in 1952-1953, was an anticlimax, at least in retrospect." Menard's work led to the discovery of the Mendacino Escarpment. Relying on deep sea soundings and seismic refraction studies, he and his colleagues demonstrated that the sea floor was neither thick nor smooth, but rather "an endless expanse of hills" that they named the Mid-Pacific Mountains. Studies by Revelle and Arthur Maxwell (b.1925) yielded the unexpected finding that heat flowed through the ocean floor at close to the same mean rate for heat flow on land, a result that suggested convection occurring beneath the ocean basins. Dredgings from the tops of seamounts revealed rocks that were recent and volcanic, suggesting confirmation of Darwin's theory of coral reef formation.⁵⁶

Revelle ensured that the expedition would also meet military objectives. He and other scientists were eager to study the structure of the ocean bottom, while the navy had

an interest in underwater sound transmission. Listening experiments done by the navy had suggested that sound arriving at a receiver traveled partly by direct transmission, and partly by reflection off the ocean bottom. In shallow water and at short distances it was difficult to distinguish the two since the signals arrive almost simultaneously. Such distinctions could only be made by doing experiments in water of 3000 fathoms or deeper and in areas of varied hydrographic conditions. The navy, as Revelle knew, had great interest in that problem and would contribute one vessel to what was a two ship operation.⁵⁷ Raitt also recognized the military relevance of his work, stating that "[M]ajor emphasis is to be placed on studies that are expected to be directly applicable to undersea warfare." His seismic refraction tests would yield knowledge of the structure of the Earth beneath the ocean; they also provided information on sound transmission frequencies and distances. He pointed out that "Bottom cores, taken in conjunction with the sound transmission measurements, will give essential data on the relation between bottom composition and the effects of bottom reflection on long-range sound transmission."⁵⁸ That was especially useful for SOFAR experiments. The deep sea work in the Marshall Islands was the cutting edge of the science; it was also the work that contributed most directly to the navy's interests. Menard realized "how greatly the operational needs of the Navy during this period influenced the collection of data that provided the basis for the forthcoming geological revolution."⁵⁹

The same emphases characterized subsequent SIO expeditions. In 1951 Revelle followed up Midpac with another cruise, Northern Holiday, and soon SIO was sending out multiple deep sea expeditions annually. Like Midpac, Scripps's Capricorn Expedition in 1952 emphasized geophysics: magnetic studies, bathymetry, coring and dredging,

bottom temperature measurements, and seismic experiments. Capricorn received support from navy agencies; it was also associated with Operation Ivy, the Atomic Energy Commission's hydrogen bomb tests in the Pacific.⁶⁰ Following Capricorn, Revelle considered appointing Hubbs the leader of the next expedition, Transpac. Hubbs and Claude Zobell made plans for a voyage that would cut across the North Pacific to the Sea of Japan and then go south to Manila Bay. The expedition to the Philippines, as Zobell called it, was one "whose primary objectives . . . may be biological," but it would also include "concurrent observations on hydrography, chemistry, bathymetry, meteorology, etc."⁶¹ But soon the expedition's itinerary came into question. In February 1953, C. N. G. Hendrix, the head of an ONR liaison office at Scripps suggested to Zobell that the expedition could obtain better results by focusing on a smaller area and omitting the track from Japan to the Philippines. The following month a Transpac conference conducted by Revelle suggested a shift in the expedition's scientific emphases. Hubbs, expressing disappointment that Revelle would not hire a prominent biologist, withdrew from the expedition, stating "it would seem probable that with a strong emphasis on the sort of data the Navy most wishes, that the biological work would not receive as much time as it would on an essentially biological trip." Following the appointment of a new expedition leader, Warren Wooster (b.1921), a chemical oceanographer who identified studies of currents and water masses as the expedition's main priority, Hendrix stated: "It is the opinion of this Office that subject cruise is of extreme importance to the U.S. Navy and should be supported in every detail. It is of particular value to those activities concerned with undersea warfare." Biological studies, according to Hendrix, would be integrated into the expedition's overall plan, but the transformation of Transpac made Revelle's and

the navy's priorities quite clear.⁶² Fisheries and biological investigations would play more of a role on the Norpac Expedition (1955), but because of military sponsorship, investigations of the circulation and diffusion of radiological materials remained a major component of those undertakings.⁶³

REVELLE, SCRIPPS AND THE BIOLOGICAL SCIENCES

Revelle's emphasis on physical and geological oceanography had consequences for marine and fisheries biology at Scripps. Even before he returned to La Jolla in 1948, Revelle knew that the institution was in the midst of considerable growth due to an expanded commitment to fisheries. The decline of the sardine, a problem before the war, became a source of even greater concern in the late 1940s. For support, biologists and leaders in the fishing industry turned to Sverdrup's expertise and SIO's access to ships, equipment, and financial resources. Based on a proposal developed by Sverdrup and fisheries experts, the state Marine Research Commission provided substantial funding for SIO, the Fish and Wildlife Service, the California Division of Fish and Game, and the California Academy of Sciences to address the sardine problem. At Scripps Sverdrup created the Marine Life Research Program (MLR) for work in physical and chemical oceanography in coordination with biological research of the Fish and Wildlife Service. He looked to Revelle, still in Washington, to assist with providing ships for the project. Sverdrup also furnished Revelle with information about the MLR program, particularly when opposition to Revelle's appointment as director made it clear that he would have responsibility for the sardine project.⁶⁴

Although Revelle had some understanding of fisheries and marine biology, he did not have the same perspective, nor did he command the same respect, as Sverdrup. As

director of the Bikini Resurvey he had provided opportunities for biologists to conduct ecological and systematics studies in the Marshall Islands.⁶⁵ The decision by the SIO faculty to appoint Revelle assistant director referred to his experience in integrating biology into a large oceanography project. Nevertheless some biologists lacked confidence in his ability to direct the MLR program. Writing to Wilbert M. Chapman (1910-1970) in 1947, Vernon Brock, one of the biologists on the Bikini Resurvey, claimed he was not impressed with Revelle's understanding of ecology. Hubbs, despite agreeing with the decision to place Revelle in charge of the MLR program, remained skeptical. In addition, Revelle did not embrace the "balanced" approach that had characterized Sverdrup's directorship. In a 1947 letter defining his views on the role SIO would play in the sardine project, Revelle stressed the value of physical oceanography. Writing to the chair of the Marine Research Committee, he stated it would be

most important to make dynamic analyses where possible of the processes in the sea, that is, the cause and effect relationships which affect sardine production....

[S]ome of the problems may be solved by treating the sardines en masse as if they were particles of a fluid somewhat similar to seawater. For this point of view, similar concepts will be involved to those of dynamic oceanography and the equations of motion and continuity may be very powerful tools.

According to Revelle, "experience in the earth sciences, particularly meteorology and oceanography," demonstrated that "wherever such a dynamical analysis of a particular aspect of the problem can be made, a great saving in time required for a solution will be effected over the 'brute force' method of statistical correlation." Scripps scientists would therefore concentrate on physical and chemical oceanography, with a view to developing

"methods for forecasting where, when, and how many sardines will be caught during any particular season." Both conceptually and methodologically, Revelle looked to the physical sciences to define the MLR program.⁶⁶

Revelle's first efforts created some tension within the cooperative sardine project. In the original program Sverdrup had indicated that SIO would have responsibility for the oceanographic work; the biological research, including egg and larval studies, sardine spawning, and recruitment would be done by the Fish and Wildlife Service. Within his first two months, Revelle proposed that SIO take responsibility for both. In addition to physical oceanographers, he planned for SIO to hire half a dozen marine biologists. That situation would give Scripps almost sole control over the use of ships, and Elton Sette (1900-1972), a Fish and Wildlife biologist who had worked closely with Sverdrup, was "much disturbed" by the proposed changes.⁶⁷ That problem was solved but others persisted. The program called for oceanographers to collect information on temperature, pressure, salinity, and current movements in surface layers over a vast area. Revelle had anticipated that such data would be the basis for developing predictive models. But both Iselin and Gordon Riley (1911-1985) expressed doubts that such a program would provide the information on current movement in surface layers that was most important to biologists. In addition, Scripps scientists were soon overwhelmed by the amount of fieldwork and ship time that the project entailed. Proposals to hire marine biologists did not materialize, and instead money went for "computers" to process and organize data.⁶⁸

Other fisheries biologists criticized what they saw as SIO's undue emphasis on research. Following the 1951 annual sardine conference, Frances Clark (1894-1987) of the California Fish and Game Commission stated that many of the papers had strayed

from the problem at hand: solving the decline of the sardine.⁶⁹ Leaders in the California fisheries industry went further, claiming that Scripps was not meeting the legislative mandate. Complaints from that sector also made their way to the office of the president of the University of California, and at a critical time for Revelle. In the fall of 1949 Eckart announced that he was stepping down as SIO director of Scripps, and again there was considerable speculation over who would succeed him. As the associate director Revelle had support, but, as in 1947, some opposed him. Many in the fisheries industry, decrying the lack of practical work being done on the sardine project, called on University of California President Robert Gordon Sproul (1891-1975) to appoint one of their own: Wilbert M. Chapman. Revelle, aware of the competition, pleaded with Sproul not to destroy Scripps by "putting it in the hands of a man [Chapman] whose interests are so narrow and so practical."⁷⁰

Revelle's comments about Chapman offer insight into his views on science and patronage. Although they worked together on a number of projects, Chapman and Revelle came from different backgrounds and represented different approaches. Chapman, trained as a fisheries biologist, became involved in policy matters after the war. After holding positions at the California Academy of Sciences and the University of Washington, Chapman in 1948 joined the State Department and sought to expand the government commitment to American fisheries both nationally and internationally. Although involved in the effort to solve the sardine problem --he had brought Sverdrup to the attention of industry leaders and helped design the project--he took an even greater interest in the tuna industry. Appointed director of the American Tunaboat Association in 1951, he was a tireless and accomplished advocate for harvesting deep-sea tuna,

developing better fish bait, boats, and equipment, and improving the processing, canning, and marketing of tuna. For Chapman, science, including oceanography, served practical social and economic objectives.⁷¹

Revelle entertained somewhat different views. Certainly he had directed applied oceanographic projects during the war. He also worked closely with government agencies, civilian as well as military, and fully supported the country's postwar political and economic objectives. But Revelle also devoted much of his attention to defining and solidifying the relationship between the navy and the oceanographic community.

Influenced by the views of Vannevar Bush, Revelle differentiated basic research, which stemmed from ideas and projects generated by scientists, from applied research, in which organizations contracted with scientists for work to meet specific objectives. Revelle fully realized that oceanography had useful, practical applications. But he also made it clear that he did not favor having SIO do contract work. He actually wrote back to agencies, such as the Beach Erosion Board, and asked them to revise their contracts to reflect the fact that SIO did only fundamental research.⁷² Revelle never went that far with the state funded sardine project, but he did indicate that "the support we receive from the fishing industry tends to be channelized, . . . towards taking routine observations which can be used for statistical studies." He worried that the objective of trying to solve a specific problem kept the Scripps staff from doing "the experimental and unorthodox work that they would like to do" on that problem. For Revelle it was work funded by ONR and other navy agencies that provided scientists with the opportunity and autonomy to do "fundamental research." Certain fields, including marine microbiology and fisheries, did not warrant such support. That work, funded to achieve specific ends, did

not provide the freedom and creativity associated with navy patronage. Nor was it, strictly speaking, part of oceanography.⁷³

Revelle, not Chapman, became the new director of Scripps, but issues concerning practical science did not disappear. Meeting in 1949, UNESCO members noted the importance of improving fisheries by developing better fishing techniques, better fish bait, and more efficient processing systems. At much the same time a National Academy of Sciences Committee on Oceanography, a committee that included Revelle, stressed many of the same themes. So too did participants in a symposium entitled "The Position of the Scripps Institution of Oceanography in the University, the State, and the Nation." Organized by Revelle, that forum enabled scientists to examine the role that engineering, contract research, and service should play in an institution like Scripps. Revelle and Chapman, among others, did not see eye to eye on those subjects. Revelle was committed to what he called "really free research."⁷⁴ But at the same time he was under pressure, from within Scripps and without, to respond to increasing demands for fisheries and oceanographic engineering projects. He did so, but in a manner that embodied his views on science and patronage.

In 1950 Revelle began efforts to incorporate fisheries, but not directly into the Scripps Institution. In June of that year he called on the university to go beyond its commitment to the sardine program and bring a new tuna fisheries organization to La Jolla. That agency was largely a result of Chapman's efforts. As a fisheries expert for the State Department, Chapman had just completed a treaty between the United States, Mexico, and Costa Rica to establish the Inter-American Tropical Tuna Commission, an organization that would undertake a wide range of projects on tuna. Chapman was

influential in having his colleague, Milner B. Schafer (1912-1970), appointed director of that commission, and with Chapman's urging Schafer contacted Revelle about locating his organization at SIO. Since Chapman was still being considered for the SIO directorship, Revelle delayed for a time. But by December 1950 he had reached an agreement with Schafer and the Tuna Commission to set up shop, not in La Jolla, but at Point Loma.⁷⁵

Revelle had also delayed because he saw the opportunity to use that acquisition as a means to promote a larger project. Since the end of World War II, scientists at the University of California had discussed creating a university-wide center for fisheries. Many considered the University of California at Davis the best location for such an institute. That was the consensus reached by Hubbs and other biologists meeting in 1949. Revelle, however, had other plans in mind. With the SIO directorship on the line, Revelle sought to make himself and the institution more visible within the university. Coupling that objective with the demands that Scripps do more in fisheries, Revelle proposed that the university establish the new institute in La Jolla. Even before finalizing the agreement with the Tuna Commission, he was writing to Sproul and calling for the creation of an additional organization: the Institute of Marine Resources (IMR). He outlined plans for a center that would be housed in La Jolla, but separate from Scripps, and would emphasize applied research projects, especially in fisheries. In July 1951 Revelle received the appointment as SIO director; six months later he had his new institute.⁷⁶

It would be two more years before IMR was up and running, and by that time the original prospectus had changed considerably. Rather than a center primarily for

fisheries biology, the institute had become an umbrella organization for beach erosion studies, city sewage projects, and the search for underwater minerals. In place of Chapman, whom he had originally proposed as IMR director, Revelle appointed a former navy colleague: Admiral Charles D. Wheelock (1897-1980), a naval architect with no experience in fisheries or oceanography. With IMR Revelle had succeeded in establishing a new, multi-faceted institution, one that significantly expanded marine related activities in La Jolla. He had also created an institution consistent with his own views. IMR was designed to "tackle the engineering problems relating to the sea" that Scripps was not "intended to deal with." As such, it allowed the "Scripps Institution of Oceanography itself to continue its attack on what the ocean is like."⁷⁷

In the mid 1950s Revelle also brought in other associated laboratories. Negotiating, at times without Sproul's full knowledge or consent, he succeeded in transferring the southwestern division of the Fish and Wildlife Service from Stanford to La Jolla. A few years later a branch of the Bureau of Commercial Fisheries was established. Through those efforts Revelle played a pivotal role in expanding fisheries biology in southern California.⁷⁸

Revelle took credit for and maintained a good relationship with those laboratories, yet he also tried to keep them at arm's length from the Scripps Institution. Some of those organizations, such as the Inter-American Tropical Tuna Commission and the Fish and Wildlife division, were government agencies and could not be incorporated into Scripps. Revelle, however, was intent on keeping the IMR separate from Scripps. He also sought to move the sardine project out from under Scripps's auspices. Originally he wanted to locate the MLR program within IMR; when that didn't work he tried to have it placed

under the Fish and Wildlife division. Those efforts failed and MLR remained within Scripps, but not because Revelle wanted it there.⁷⁹

When Revelle began promoting marine biology in the early 1950s, he did so through SIO, not its associated laboratories, and with his views on patronage and research firmly in mind. He did not approach ONR, although by that time it was supporting work in biology. Instead he turned to the Rockefeller Foundation and hoped that it would help "to develop here a new synthetic biology." Writing to Warren Weaver (1894- 1978), the director of the Rockefeller Foundation who fostered work in molecular biology, Revelle noted that the establishment of IMR "would inevitably and seriously affect its sister organization, the Scripps Institution of Oceanography." He hoped IMR's presence would stimulate "our fundamental work in marine biology," but to do so "we must gain a greater understanding than we now have of the dynamics of marine populations --the factors which control the growth, numbers, distribution, behavior, chemistry, and energy relationships of marine organisms." Contrasting Scripps with IMR and MLR, Revelle maintained that effective research on those problems required not only good scientists but "a climate of freedom from economic pressure." Revelle called for a new marine biology, one that relied on experimentation and employed modern tools and theoretical principles. Grounded in genetics and evolutionary theory, such a program would enable researchers to examine organisms in relationship to their "chemical ecology," to analyze how "purely physical phenomena such as turbulence and diffusion" related to nutrition and optimal size of organisms, and to understand how movement of water masses influenced population structure. An understanding of energetics, he stated, could open a "new discipline of organisms' engineering, under the Division of Physical Oceanography."

That work, when understood in terms of population dynamics, would enable scientists "to follow, predict, and eventually control the fluctuations in abundance." Revelle was calling for a "new biology," but one based on his views of physical oceanography.⁸⁰

CONCLUSION

Revelle's success in obtaining the Rockefeller Foundation grant, as well as four new faculty positions in biology,⁸¹ offers further evidence of his entrepreneurial abilities. In the course of ten years he had significantly changed the Scripps Institution and science in San Diego. From a small seaside laboratory SIO had become a world leader in oceanography, renowned for its deep sea expeditions and discoveries in geophysics. He had also fostered considerable expansion in other areas by bringing in a number of "associated laboratories": facilities in La Jolla and Point Loma devoted to fisheries and oceanographic engineering. Not all of that growth was due to Revelle; the rationale and support for the sardine project came from different sources. Nevertheless, by the mid 1950s there existed a large and growing complex for oceanography and marine sciences, much of it due to Revelle's efforts.

And yet Revelle had also constructed a landscape with a particular topography, one that included institutions that served very different purposes. Many of the associated laboratories and institutions that were not part of Scripps were located in Point Loma, not La Jolla. More important they received funding from a wide variety of contractors, and served social, economic, and political objectives. Although Revelle hesitated to support such work early on, by the mid 1950s he was devoting an increasing amount of money and resources to fisheries and other subjects. Scientists from SIO as well as the other laboratories participated in multi-national expeditions designed to foster internationalism.

The search for new fisheries, Revelle often claimed, would provide the world's population with a much needed source of protein. Such efforts also served as a means of appealing to third world countries in the midst of the Cold War.⁸²

Yet Revelle also remained committed to a different vision of science, one that informed his interest in bringing molecular biology to SIO. For all his emphasis on the new tools and techniques of the "molecular revolution," Revelle's application to the Rockefeller Foundation bore striking similarities to his earlier effort to define the MLR program. In both cases, marine biology would be placed squarely within the framework of the physical sciences. It was principally the physical and chemical parameters, and how organisms responded to those conditions that was important, not the organisms or populations themselves. The new marine biology that he called for would embody the approach and objectives of the physical sciences: an emphasis on experimentation, analytical rather than descriptive work, for the purposes of prediction and control. Revelle had turned to the Rockefeller Foundation for support, but with an understanding and appreciation of physical oceanography grounded in military experience and cognizant of military needs and objectives. Moreover, that view of science, as a form of pure research and rarified intellectual activity, led Revelle on an entirely new undertaking: the development of the University of California, San Diego. Claiming that such a university "could evolve naturally" from SIO, he called for an institution that would offer "increased opportunities for basic research, . . . something like a publicly supported Cal Tech, . . ."⁸³ With support from military and military-industrial patrons, Revelle's original plan for the university emphasized the physical sciences.

Revelle's activities in La Jolla followed a double track: one of science in his sense of pure research and intellectual creativity; the other, science to meet specific goals. It is possible to view the configuration that he developed as a manifestation of oceanography. Long considered as an "ensemble" of sciences dealing with the sea, it was a multi-dimensional field of inquiry. In addition, fisheries biology, as a practical commercial enterprise, was often separated from oceanography. Yet the particular configuration that emerged at Scripps in the years between 1940 and 1955 was not just a general feature of the science. Rather it was in an important sense a consequence of World War II. That conflict had a profound impact on oceanography. With the war came an emphasis on new areas of inquiry, namely geophysics and underwater sound, and a reliance on a vast array of new instruments. Perhaps most important, the war changed the political economy of the science, with the navy emerging as the dominant patron.. The navy, like other branches of the military, placed a premium on the physical sciences. It also emphasized the distinction between fundamental and applied research. Revelle embraced both. Indeed he made the distinction concrete, constructing a disciplinary and institutional landscape that incorporated those differences. While recognizing and accepting the importance of practical science, he reified the fundamental research that he associated with navy support and physical science. The impact of military patronage on oceanography at Scripps was evident in far more than the financial and material support provided by the navy. Through Revelle's efforts it was instantiated in the conceptual, educational, and institutional features that characterized SIO at mid century.

ACKNOWLEDGMENTS

I am grateful to Deborah Day for her help and guidance in using the archives at the Scripps Institution and to William Roberts at the Bancroft Library, University of California, Berkeley. At the National Archives Marjorie Ciarlante and Barry Zerby offered expert assistance with civilian and military records. Gary Weir generously allowed me to examine his manuscript on the history of naval oceanography. Thanks to the participants at the Maury II Workshop on the History of Oceanography, especially Deborah Day, Jane Maienschein, Eric Mills, Naomi Oreskes, and Gary Weir for their comments on this paper.

ARCHIVES

Bureau of Ships Records, National Archives, College Park, Maryland	BS
Wilbert M. Chapman Papers, University of Washington, Seattle, Washington	WMC
Chief of Naval Operations Records, National Archives, College Park, Maryland	CNO
Carl L. Hubbs Papers, Archives, Scripps Institution of Oceanography, La Jolla, California	CLH
Hydrographic Office Records, National Archives, Washington, D.C.	HO
Institute of Marine Resources Records, Scripps Institution of Oceanography, La Jolla, California	IMR
National Archives, College Park, Maryland	NACP
National Archives Record Group	RG
National Archives, Washington, D.C.	NADC
National Defense Research Committee Records, National Archives, College Park Maryland	NDCR
Office of Naval Research Records, National Archives, College Park, Maryland	ONR

Office of Scientific Research and Development Records, National Archives College Park, Maryland	OSRD
Roger Revelle Papers, Archives, Scripps Institution of Oceanography, La Jolla, California	RR
Scripps Institution of Oceanography Archives, La Jolla, California	SIOA
Scripps Institution of Oceanography, Office of Director Records	SIOD
Scripps Institution of Oceanography Subject Files	SIOSF
University of California, Office of the Presidents' Records, Bancroft Library University of California, Berkeley	UCPR

NOTES

1. For archival abbreviations, see ARCHIVES, at the end of the article. Dayton E. Carritt, Denis L. Fox, Carl L. Hubbs, Martin W. Johnson, G. F. McEwen, Walter H. Munk, Norris W. Rakestraw, Marston C. Sargent, Francis P. Shepard to Robert Gordon Sproul, 24 September 1947, UCPR, CU-5, series 4, box 32, folder 27; H. U. Sverdrup to Sproul, 7 December 1947, UCPR, series 4, box 32, folder 27.
2. Carl L. Hubbs to Harald U. Sverdrup, 3 September 1947; and Carl L. Hubbs to Robert Gordon Sproul, 24 September 1947, both in CLH, box 33, folder 44, "Scripps Institution of Oceanography Director, July 31 1947-September 24, 1947," SIOA. [Roger Revelle], "Oceanography in the Navy Postwar Program," nd [17 October 1947], SIOD (Revelle), "Operation Crossroads, 1946," box 97, folder 17, SIOA; [Roger Revelle], "Military Aspects of the Geophysics Branch Program," SIOSF, "U.S. Navy Office of Naval Research," box 26, folder 36, SIOA.

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5. On Sverdrup's contracts: H. U. Sverdrup to O. E. Sette, 22 October 1940, SIOD (Revelle), box 5, Correspondence 1938-1940; H. U. Sverdrup to Robert Gordon Sproul, 27 January 1941, SIOD (Sverdrup), box 1, Correspondence January -June 1941, SIOA. On Revelle's grants: Roger Revelle to C.R. Longwell, 24 December 1938, RR, Correspondence Series, box 1, folder 57, SIOA; and Roger Revelle to A. I. Levorsen, 5 April 1940, RR, box 1, folder 65.

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9. On transferring Sumner: Thomas Wayland Vaughan to W. W. Campbell, 14 May 1925, SIOD (Vaughan), box 1, folder 9, Correspondence May -June 1925; Thomas Wayland Vaughan, "Data Pertaining to Scripps Institution of Oceanography," 24 June 1925, SIOD (Vaughan), box 1, folder 9, Correspondence May -June 1925; Thomas Wayland Vaughan to Robert Gordon Sproul, 25 August 1930, SIOD (Vaughan), box 1, folder 69, Correspondence July-August 1930.
10. Thomas Wayland Vaughan to W. M. Hart, 19 March 1929, SIOD (Vaughan), box 1, folder 57, Correspondence March 1929; Thomas Wayland Vaughan to S.C. Brooks, 23 July 1929, SIOD (Vaughan), box 1, folder 59, Correspondence July 1929..
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12. Thomas Wayland Vaughan to Robert Gordon Sproul, 10 May 1932, SIOD (Vaughan), box 2, folder 31, Correspondence May 1932; Thomas Wayland Vaughan to George D. Louderback, 25 November 1935, SIOD (Vaughan), box 3, folder 112, Correspondence October-November 1935; Thomas Wayland Vaughan to George D. Louderback, 28 December 1935, SIOD (Vaughan), box 3, folder 114, Correspondence December 1935.

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21. [Columbus O'Donnell Iselin], "Sound Transmission in Sea Water: A Preliminary Report," 1 February 1941, 1-22, 72-80, RG 227, OSRD, entry 29, box 752, folder WHOI, NACP. The acronym sonar was not coined until 1942, however, in this paper the terms sonar and echo ranging will be used interchangeably even for years prior to that date.

22. Quote is from Iselin, "Sound Transmission in Sea Water," 81. Columbus O'Donnell Iselin to Vannevar Bush, nd [1940], RG 227, NDRC, entry 77, box 4, folder 01.90. On UCDWR: Vern O. Knudsen to Frank B. Jewett, 10 June 1941, RG 227, NDRC, entry 78, box 52, folder General UC #1, May -December 1941; Vern O. Knudsen to John

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23. A. D. Burhans to H. U. Sverdrup, 7 May 1940, SIOD (Sverdrup), box 1, Correspondence January -June 1940, SIOA. On Revelle's additional navy work while still at Scripps: Naval Reserve Form, filled out 15 December 1940, RR, Biographical Series, box 1, folder 28 Navy Service, 1936-37, 1940-42; Roger Revelle to Charlie Anderson, 4 March 1941, RR, Biographical Series, box 2, folder 3, Correspondence January-April 1941. Revelle referred to the completion of the report in a completed Fitness Report, Naval Reserve Office, 4 October 1941, RR, Biographical Series, box 1, folder 28.

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NP22/S/68 #2; and Vern O. Knudsen to John T. Tate, 22 January 1942, NDRC, entry 78, box 52, folder, General-UC. On the dispute between Ruble and Gaylord P. Harnwell: J. A. Furer to Director Navy Radio and Sound Laboratory, 17 July 1942, NDRC, entry 77, box 8, folder 03.00 harbor defense.

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29. Hydrographer to Coordinator of Research and Development, 4 January 1943, BS General Correspondence 1940-1945, box 1208 S(68) # 22; Edwin H. Colpitts to Roger Revelle, 1 March 1943, BS General Correspondence 1940-1945, box 1210 S68 (1) #25; Roger Revelle to Director Woods Hole Oceanographic Institution, 15 September 1944, BS General Correspondence 1940-45, Electronics Division, box 231, folder sonar, September-December 1944.

30. Roger Revelle to Commander in Chief, U.S. Fleet, Readiness Division, 14 June 1943, BS General Correspondence 1940-1945, Radio Division, box 109, folder 4; Conference, 21 January 1944, BS, Secret Correspondence 1944, box 184, folder January-February 1944.

31. Martin W. Johnson, "Underwater Sounds of Biological Origin," 15 February 1943, UCDWR Report No. 28; and idem, "Underwater Noise and the Distribution of Snapping Shrimp with Special Reference to the Asiatic and the Southwest and Central Pacific Areas," 1 January 1944, UCDWR Report U146, both in UCDWR Reports, boxes 2-3, SIOA. Reference to work done by the UCDWR listening group in conjunction with the NRSL is in: Navy Radio and Sound Laboratory, "Report of Survey of San Francisco Harbor." Also F. Alton Everest and Elva M. Everest, *World War II Underwater: An Engineer Called to San Diego, California for Wartime Research in Underwater Sound*, unpublished manuscript, 1992.

32. The quote is from Iselin, Application of Oceanography, 16. NDRC, The Use of Bottom Sediment Charts, May 1943, RG 37, HO Security Classified General

Correspondence, 1924-1945, entry 49, box 30, folder A10-1/S68 428232.

Correspondence between Revelle and scientists at WHOI and UCDWR on bottom sediments is in: HO Security Classified General Correspondence, entry 49, box 30, folder A10/1/S68 (428232)a.

33. Conference, Military Requirements for Oceanography, 11 November 1942, RG 298, ONR, Office of the Coordinator of Research and Development, box 62, folder Oceanographic Data, Volume I, NACP. Roger Revelle to Columbus O'Donnell Iselin, 10 August 1943, BS General Correspondence 1940-45, Radio Division, box 109, folder underwater sound #4.

34. Edwin H. Colpitts to Gaylord P. Harnwell, 27 June 1944, NDRC, entry 79, box 6, folder Harnwell. Rawson Bennett to Harald U. Sverdrup, 9 May 1944, HO Security Classified General Correspondence, entry 49, box 31, folder A10-1/S68 428232.

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38. Columbus O'Donnell Iselin to Harald U. Sverdrup, 10 April 1946, and Sverdrup to Iselin, 12 April 1946, both in SIOSF, "Expeditions: Operation Crossroads, March-April 1946," box 6, folder 28.

39. "Minutes of the Meeting Held in the Hydrographic Office," 19 October 1945, SIOSF, "U. S. Navy Hydrographic Office 1945-46," box 26, folder 25. Commander Amphibious Forces to Commander in Chief, U.S. Fleet, 20 August 1945, RG 38, Commander in Chief Confidential Correspondence 1945, box 1805, folder H1-(3) #1. E. W. Mills to Hydrographer 11 December 1945, Deputy CNO (Air), box 3, folder H1 (1) #!. From late 1943 until the end of the war, Admiral Julius A. Furer, the Navy Coordinator of Research and Development, took part in numerous discussions on postwar research, including Charles E. Wilson's committee and what became the Research Board for National Security: ONR, box 52, includes three large folders on postwar research.

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41. Elmer Hutchisson to Gaylord P. Harnwell, 29 September 1944, and 28 December 1944, NDRC, entry 78, box 47, folder Demobilization III. On the proposed expansion of the Hydrographic Office and transfer of some of its activities to SIO: Richard H. Fleming, C. O' Donnell Iselin, Lyman Spitzer, and H. U. Sverdrup, Memorandum for Commander Roger Revelle Summarizing Conclusions Reached at a Conference at La Jolla, January 10-13, 1945, SIOSF, "Contracts: Summaries and General

1945-46," box 5, folder 55, SIOA. H. U. Sverdrup to Roger Revelle, 20 January 1945, NDRC, entry 78, box 58, folder Demobilization III.

42. Gaylord P. Harnwell to Edwin H. Colpitts, 1 November 1944; and Gaylord P. Harnwell, "Status Report," 9 November 1944, NDRC, entry 78, box 47, folder Demobilization III. The disposition of projects to the Naval Research Laboratory and the Navy Radio and Sound Laboratory was worked out in a conference held at UCDWR on 18 November 1944. On MPL: A. B. Jones to Regents of the University of California, 12 December 1944, BS General Correspondence 1940-45, Radio Division, box 221, folder sonar, December 16-31, 1944. Although signed by Jones, the letter was written by Revelle.

43. Fleming, et al., Memorandum for Revelle. Criticisms of costs and complaints: Iselin to Sverdrup, 10 April 1946, and Sverdrup to Iselin, 12 April 1946.

44. Fleming, et al., Memorandum for Revelle. [Harald U. Sverdrup], Memorandum on Postwar Studies of the Oceanography of the Surface Layers, 31 May 1945, SIOD (Sverdrup), box 1, Correspondence May-June 1945.

45. On arranging for BT work: Hutchisson to Harnwell, 28 December 1944; and E. H. Colpitts to Roger Revelle, 26 December 1944, NDRC, entry 79, box 7, folder Navy Department (Revelle), November 13, 1943-1944. On contracts: Bureau of Ships to Director, University of California Division of War Research, 21 March 1945, NDRC, entry 78, box 58, folder Demobilization III.

46. The quote is from [Revelle], "The Geophysics Branch Program," A more complete discussion is in [Revelle], "Oceanography in Navy Postwar Program." See also Ronald Rainger, *Science at the Crossroads: the Navy, Bikini Atoll, and American*

Oceanography in the 1940s, Historical Studies in the Physical and Biological Sciences, 2000, 30: 349-371.

47. Revelle was listed as a member of the Panel on Oceanography of the Committee on Geophysics and Geography of the Research and Development Board, 10 February 1949, SIOD (Revelle) "Research and Development Board, 1949," box 3. Detlev W. Bronk to Roger Revelle, 9 April 1948, SIOD (Revelle), box 1, Correspondence Series, 1948. Recommendations to the National Research Council by the Pacific Science Conference held at the National Academy of Sciences, Washington, D.C. June 6-8, 1946, released to the public 28 June 1946, SIOSF, "Pacific Science Board, National Research Council, June 1946-1947," box 27, folder 21; SIOD (Revelle), Correspondence Series, boxes 2-3, folders on National Research Council Committee on Amphibious Operations, 1950-1954.

48. SIOSF, "Research: U. S. War Department Beach Erosion Board Contract W-49-055-ENG3, Investigations of Fundamental Principles Governing Movement of Beaches and Near Shore Materials," box 17, folders 5-8. On the Air Force Cambridge Research Lab: Roger Revelle to H. E. Landsberg, 12 April 1953, SIOSF, "Research Air/Sea Boundary, 1953," box 17, folder 18. On the Visibility Laboratory: Roger Revelle to S. Q. Duntley, 31 January 1952, SIOD (Revelle), box 3, Correspondence November 1951-January 1952.

49. On Revelle's role in helping to obtain ships see: H. U. Sverdrup to Robert Gordon Sproul, 20 February 1947, SIOSF, box 13, folder 11; William A. Rice to Carl Hubbs, 25 November 1947, SIOSF, box 20, folder 48. On ONR: Roger Revelle to Gordon Lill, 23 March 1949, SIOD (Revelle), box 1, Correspondence March -April 1949.

Budgets for Scripps during the years that Eckart and Revelle were directors are sporadic. This estimate comes from a listing of just the contracts from ONR and the Bureau of Ships dated 5 May 1948, that totaled \$963,475: UCPR, folder 1948:414.

50. The quote is from Roger Revelle to Harald U. Sverdrup, 6 January 1948, SIOD (Revelle), box 1, Correspondence January -February 1948. Also: Roger Revelle and Carl Eckart to Code 418, 20 May 1949, SIOSF, "Research: Bureau of Ships, SOFAR 1946-47," box 16, folder 52; Carl Eckart to Roger Revelle, 10 1949, SIOSF, "Bureau of Ships, SOFAR, 1948-52," box 16, folder 53.

51. Carl Eckart to James H. Corley, 24 May 1948, SIOD (Revelle), box 1, Correspondence May-June 1948. On shift in doctoral degrees: Raitt and Moulton, Scripps Institution of Oceanography, Appendix II, 192-194. The numbers for the 1930s and 40s were sixteen in the fields of biology and microbiology; eight in oceanography.

52. The quotations are from Carl Eckart to Vern O. Knudsen, 30 January 1950, SIOD (Revelle), box 1, Correspondence January 1950. On ONR support for training, both military and civilian: SIOSF, box 1, folders 65-69 Contracts N6 ORI III 1946-1953.

53. H. H. Hess, Drowned Ancient Islands of the Pacific Basin, American Journal of Science, 1946, 244:772-791. On the Bikini Resurvey: K. O. Emery, J. I. Tracey, Jr., and H. S. Ladd, Geology of Bikini and Nearby Atolls, U.S. Geological Survey Professional Paper, 260A (1954). Ewing's work is discussed in H.W. Menard, The Ocean of Truth: A Personal History of Global Tectonics (Princeton: Princeton University Press, 1986), 30-49.

54. Roger Revelle, "Proposed University of California Mid-Pacific Expedition," 10 October 1949, SIOD (Revelle), box 1, Correspondence October 1949.

55. Roger Revelle to Allyn C. Vine and Beauregard Perkins, 9 January 1950, SIOSF, "Expeditions: Midpac, R/V Horizon, Correspondence May-June 1950," box 6, folder 36, SIOA. Commanding Officer and Director, Navy Electronics Laboratory to Chief, Bureau of Ships, 6 January 1950, SIOSF, "Expeditions: Midpac, Correspondence January-April 1950," box 6, folder 36. R. S. Dietz to R. R. Revelle, 7 June 1950, SIOSF, "Expeditions: Midpac, Correspondence May-June 1950," box 6, folder 37.

56. Menard, The Ocean of Truth, 44-56, on 44.

57. Revelle to Vine and Perkins; "Proposed Mid-Pacific Expedition. Proposed Studies Related to Underwater Sound and Undersea Warfare Problem," Prepared by Joint SIO-NEL-MPL Planning Committee, nd [January 1950], SIOSF, "Expeditions: Midpac, Correspondence January-April 1950," box 6, folder 36. [Revelle], "Oceanography in Navy Postwar Program."

58. Russell W. Raitt, "Mid-Pacific Expedition, 1950," 1 June 1950, SIOSF, "Expeditions: Midpac, Correspondence January-April 1950," box 6, folder 37.

59. Menard, Ocean of Truth, 72.

60. P. L. Hooper to Commander Joint Task Force 132, 26 June , 1952, SIOSF, "Expeditions: Capricorn, June-July 1952," box 7, folder 6; "Ivy List," SIOSF, "Expeditions: Capricorn, February-May 1952," box 7, folder 5.

61. Memorandum, Claude E. Zobell to Messrs. Bramlette, Corcoran, Fox, Frautschy, Goldberg, Hale, Hand, Haxo, Holmes, Horrер, Johnson, Manar, Norris, Rakestraw, Schaefer, Snodgrass, Wooster, and others actively interested in participating in the expedition to the Philippines, 21 November 1952, SIOSF, "Expeditions: Transpac, July 17-December 1, 1953," box 7, folder 29.

62. C. N. G. Hendrix to Claude E. Zobell, 25 February 1953; "Trans-Pac Conference in March 1953, materials taken from notes Dr. Revelle made on blackboard"; Memorandum, Carl L. Hubbs to The Director, 3 March 1955; Warren Wooster to Claude E. Zobell, 13 March 1953; Claude E. Zobell, Trans-Pac Progress Report, No. 4, 22 April 1953; C. N. G. Hendrix to Director, Office of Naval Research, Pasadena Branch, 24 April 1953; C. N. G. Hendrix to Chief of Naval Research, 1 May 1953, all in SIOSF, "Expeditions: Transpac," box 7, folders 29-31.

63. Joseph L. Reid to John S. Marr, 19 May 1954, SIOSF, "Expeditions, Norpac," box 7, folder 43; also related materials in folders 43-48. Sponsorship by the Armed Forces Special Weapons Project is in: Roger Revelle to Russell Barthell, 1 June 1954, UCPR, folder 1954:414.

64. Meeting of the Sardine Research Committee, 13 March 1947, SIOSF, "Marine Life Research Program, January-March 1947," box 13, folder 11. On Chapman's role in involving Sverdrup: Wilbert M. Chapman to Montgomery Phister, 26 December 1946, CLH, box 24, folder 6, "Marine Life Research." On Sverdrup's meetings with navy representatives about boats: H. U. Sverdrup to Robert Gordon Sproul, 17 March 1947, SIOSF, "Marine Life Research Program, January-March 1947," box 13, folder 11. Also note 49 above.

65. Of the twenty-seven papers, seven were on biology including paleontology. Those included: John W. Wells, Recent Corals of the Marshall Islands, U.S. Geological Survey Professional Paper, no. 260-I; J. Harlan Johnson, Calcareous Algae of Bikini Atoll, U.S. Geological Survey Professional Paper, no. 260-M; Ruth M. Todd and Rita

Post, Smaller Foraminifera from Bikini Drill Holes, U.S. Geological Survey Professional Paper, no. 260-O.

66. Carritt, et. al., to Sproul, 24 September 1947; Vernon E. Brock to Wilbert M. Chapman, 16 September 1947, WMC, box 10, folder 18. Roger Revelle to Colonel I. M. Isaacs, 29 November 1947, SIOSF, "Marine Life Research Program, 1947," box 13, folder 15.

67. Harald U. Sverdrup, "The Sardine Problem," SIOSF, "Marine Life Research Program, January-May 1948," box 13, folder 16. [Roger Revelle], "Marine Life Research Program," SIOSF, "Marine Life Research Program, January-May 1948," box 13, folder 16. On dispute with Revelle: Carl Hubbs to O. E. Sette, 9 April 1948, CLH, box 24, folder 7; O. E. Sette to Roger Revelle, 11 May 1948, SIOSF, "Marine Life Research Committee, January -May 1948," box 13, folder 16.

68. Columbus O'Donnell Iselin to Roger Revelle, 5 October 1949, SIOSF, "Marine Life Research Program, October 1949," box 13, folder 27; Gordon A. Riley to Roger Revelle, 8 December 1950, SIOSF, "Marine Life Research Program, October 1949," box 13, folder 32. On efforts to hire biologists: Carl Hubbs to Wilbert M. Chapman, 10 May 1948, WMC, box 10, folder 18. On problems noted by MLR scientists: Warren Wooster to Roger Revelle, 19 December 1950, SIOSF, "Marine Life Research Program, November-December 1950," box 13, folder 32; Paul L. Horrer to Distribution List, 10 December 1951, SIOSF, "Marine Life Research Program, November-December 1951," box 13, folder 59.

69. Frances N. Clark to All Who Attended 1951 Conference, 13 March 1952, SIOSF, "Conferences: Sardine Conference 1952-53," box 3, folder 42.

70. On opposition to Revelle within Scripps: Denis Fox, Carl Hubbs, Francis P. Shepard, and Claude Zobell to Robert Gordon Sproul, 12 May 1950, and 31 October 1950, UCPR, CU5, series 4, box 32:27. On opposition from fisheries industry: James H. Corley to Robert Gordon Sproul, 18 September 1950, UCPR, folder 1950:414:4; James H. Corley to Robert Gordon Sproul, 9 March 1951; and Don T. Saxby to James H. Corley, 11 January 1951, both in UCPR, folder 1951: 414:2. The quote is from Discussion, Robert Gordon Sproul and Roger Revelle, 26 March 1951, UCPR, CU5, series 4, box 32:27.

71. Harry N. Scheiber, Pacific Ocean Resources, Science, and Law of the Sea: Wilbert M. Chapman and the Pacific Fisheries, Ecology Law Quarterly, 1986, 13:383-534.

72. Revelle to Landsberg, 12 April 1953. On the Beach Erosion Board: Roger Revelle memo on Beach Erosion Board Contract, 3 April 1952, SIOSF, box 16, folder 8; Roger Revelle to President, Beach Erosion Board, 7 April 1952; and Roger Revelle to Murrough P. O'Brien, 11 April 1952, both in SIOSF, box 16, folder 8. Vannevar Bush, Science-The Endless Frontier (Washington, D.C.: U.S. Government Printing Office, 1945).

73. Quotations are from the transcript of the conference on "The Position of the Scripps Institution of Oceanography in the University, the State, and the Nation," March 1951, on 56, SIOSF, "Conference: 'The Position of the Scripps Institution of Oceanography in the University, the State, and the Nation,' Charter Day, 1950-February 1951," box 5, folder 43, SIOA. See note 52 above on Scripps's curriculum.

74. Roger Revelle to Knowles A. Ryerson, 2 January 1950, SIOD (Revelle), box 1, Correspondence January 1950. Committee on Oceanography of the National Academy of Sciences, Oceanography 1951: A Report on the Present Status of the Science of the Sea (Washington, D.C.: National Academy of Sciences-National Research Council, 1952), 10-11, 13-14. Discussion over contract research and other issues occurs throughout the transcript, "Scripps, the University, the State and the Nation." Examples of the differing views of Revelle and Chapman can be found on 82, 97. The quote is in: Roger Revelle to Harald U. Sverdrup, 10 May 1950, RR, Correspondence Series 1950, box 23, folder 13.

75. Roger Revelle to Robert Gordon Sproul, 20 June 1950, UCPR, CU5, series 4, box 32:29; Milner B. Schaefer to Roger Revelle, 19 October 1950, UCPR, CU5, series 4, box 32:29; and Roger Revelle to Milner B. Schaefer, 18 December 1950, CLH, box 22, folder 43. Schaefer had expressed his willingness to transfer to the west coast several months before: Milner B. Schaefer to Wilbert M. Chapman, 20 March 1950, WMC, box 13, folder 12.

76. On support for Davis: Paul R. Needham, Boyd W. Walker, Tracy I. Storer, and Carl L. Hubbs, A Memorandum to President Sproul and the Appropriate Authorities of the Berkeley, Los Angeles, Davis, and La Jolla Campuses Reporting Consensus of a Conference Held at Berkeley, 17 December 1949, SIOSF, "Research: Development of Research and Instruction in Fish and Fisheries, University of California, 1950," box 17, folder 14, SIOA. Revelle to Ryerson, 2 January 1950; Roger Revelle to Robert Gordon Sproul, 7 November 1950, SIOD (Revelle), box 1, Correspondence November 1950. The proposal for the institute was described in: Roger Revelle to Robert Gordon Sproul, 5

October 1951, UCPR, CU5 series 4, box 32:29. On the university committee's favorable report on the institute: Baldwin M. Woods to Robert Gordon Sproul, 13 December 1951, UCPR, CU5, series 4, box 32:29.

77. Revelle's early emphasis on fisheries at IMR is in: Revelle to Sproul, 7 November 1950; and in the list of research projects attached to Roger Revelle to Baldwin M. Woods, 1 December 1951, CLH, "Institute of Marine Resource, General 1951-1954," box 22, folder 24. By contrast see list of research projects in Annual Report of the IMR, 23 April 1956, IMR, Executive Committee and Advisory Council, 1953-1959, box 7, folder 392, SIOA. Revelle had many discussions with Murrough P. O'Brien about appointing Wheelock and creating a center for marine engineering as well as fisheries projects: Roger Revelle to Murrough P. O'Brien, 14 May 1953, 14 July 1953, 2 1953, all in IMR, Office of the Director Reports, box 6, folders 376 and 377, SIOA. Revelle's recommendation of Wheelock is in IMR, Minutes of the Organization Meeting, Executive Committee, 23 November 1953, box 7, folder 392. The quote from Revelle is in "Proposal for the Institute of Marine Resources," Executive Committee and Advisory Council, January-September 1953, box 6, folder 376.

78. Roger Revelle to John C. Marr, 14 February 1954, SIOD (Revelle), box 2, Correspondence February-April 1954.

79. Revelle's effort to transfer MLR to the IMR is in: IMR, Minutes of the Organization Meeting, 23 November 1953, box 7, folder 392. On his effort to transfer that program to the Fish and Wildlife Service: Revelle to Marr, 14 February 1954.

80. Roger Revelle to Warren Weaver, 27 November 1953, SIOD (Revelle), box 2, Correspondence November 1953-January 1954; Roger Revelle to Warren Weaver, 23

August 1952, SIOD (Revelle), box 2, Correspondence, August 15-31, 1952; "Integrated Research Program," attached to Roger Revelle to Warren Weaver, 14 November 1952, SIOSF, "Marine Biology Program and Rockefeller Grant, 1952-1953," box 16, folder 47.

81. Elizabeth Noble Shor, Scripps Institution of Oceanography: Probing the Oceans 1936 to 1976 (San Diego: Tofua Press, 1978), 202-204.

82. [Roger Revelle], "Prospectus of the Proposed Institute of Marine Resources." State Marine Research Committee Meeting Minutes, box 1, volume 1, November 14, 1951, SIOA; Tanya Levin, "Finding Fish: U.S. Oceanography and Democratization in the 1960s," paper presented at Maury II Conference on the History of Oceanography, June 17, 1999, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

83. Roger Revelle to Robert Gordon Sproul, 5 August 1955; Ronald Rainger, *Building Science in Cold War California: Roger Revelle, the Scripps Institution, and the University of California, San Diego*, unpublished manuscript.

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Originally published as: Rainger, Ronald. "Patronage and Science: Roger Revelle, the U.S. Navy, and Oceanography at the Scripps Institution." *Earth sciences history* : journal of the History of the Earth Sciences Society 19(1):58-89, 2000. This article is reprinted courtesy of the History of the Earth Sciences Society from *Earth Sciences History*, 2000, 19:58-89.

