Around Buzzards Bay to a World of Ocean Science: A Personal Perspective

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Abstract Reading books, a chemistry set, living by the sea, and a chance attendance by John Farrington at a seminar led to doctor of philosophy studies in ocean sciences at the Graduate School of Oceanography, University of Rhode Island, with a focus on organic chemicals in estuarine ecosystems. An unexpected discovery of a chronic oil pollution problem during these studies set a course for a career of research at the Woods Hole Oceanographic Institution focused on the biogeochemistry of biogenic organic chemicals and organic chemicals of environmental concern such as oil chemicals and polychlorinated biphenyls. This involved cruises to deep open ocean, continental margin, and coastal ecosystems. Several times, the research was influenced by unexpected observations opening important avenues of inquiry. Details of portions of the ocean carbon cycle, especially water column particles and surface sediments, were unraveled. Environmental quality-related research led to activities at the science-policy interface. These laboratory group efforts have been recognized by my election as a fellow of the American Geophysical Union and the American Association for the Advancement of Science, among other recognitions.

1. Introduction

Reflecting on my life has allowed me to understand how reading books as a child, a chemistry set, the intense international rivalry in the 1950s through the 1980s between the United States and the USSR, (known as the Cold War), an easy day’s travel proximity to a marine research complex, and a chance encounter with a scientific seminar open to the public launched a rewarding career in ocean research and education. The focus has been on organic chemicals in marine ecosystems, both natural organic chemicals and those of environmental concern such as polychlorinated biphenyls (PCBs). This article traces the twists and turns and some of the important influences during my journey of exploring nature and how the results were brought to the science-policy interface. Although this article is about my career in scientific research, I have included brief statements about immediate family. They were first and foremost in my life.

1.1. Early Days

I was born 25 September 1944 in New Bedford, Massachusetts, a city with an ongoing maritime history, and thus, I grasped as a teenager the importance of the ocean. Looking across Buzzards Bay on a clear day, I could glimpse the town of Falmouth, Woods Hole, and the Elizabeth Islands. Later, I would make a journey around Buzzards Bay to a world of ocean science.

My mother made certain I had a supply of books to read. One book was an age-appropriate biography of Marie Curie, Nobel Prize in Chemistry laureate. This was my introduction to chemistry and to the world of scientific research. I soon had a chemistry set and delved into experiments. However, I was not a bookworm or recluse in my early basement lab! I enjoyed pickup sports games, swimming, riding my bicycle, and exploring marshes in the summer.

The Cold War resulted in policies that encouraged students with interest and some ability in science, mathematics, or engineering to focus in those areas. We were the “Sputnik generation” because of the wake-up call for the United States when the USSR orbited Sputnik, the first artificial satellite in 1957.

I considered a military career to serve my country. An appointment to a military academy had the advantage of launching that career and also providing a college education without many expenses. The financial aspects were important since there were minimal funds for my college education. I earned an appointment to the U.S. Coast Guard Academy and first alternate appointment for the U.S. Naval Academy. However, during Swab Summer at the Coast Guard Academy (the first summer), I had trouble with a knee that had
been previously injured playing football. I was dismissed with a preexisting medical condition midsummer. What to do about college?

1.2. Undergraduate Years

Fortunately, there was a small 4-year college nearby, New Bedford Institute of Technology. There were still openings in textile chemistry, and the tuition seemed reasonable if I found a part-time job. I could live at home, further saving money. I secured a job three nights a week and Saturdays as an assistant mechanic for automatic pinsetters at a bowling alley. I also received a scholarship that paid some of the tuition. I was the first in my family to attend college.

I was still thinking of a military career and exercised to strengthen my knee. After acceptance to Platoon Leaders Class (Aviation) Training of the U.S. Marine Corps, I was off to Quantico, Virginia, for the first of two summer training stints. Several weeks later, back I came to New Bedford, knee in a cast and an honorable discharge (medical) from the U.S. Marine Corps. I am not certain I would have completed the rigorous training. However, I have maintained the self-promise that I would serve my country in some way. A career in science beckoned.

I switched to the BS in chemistry curriculum in what was now Southeastern Massachusetts Technological Institute, having developed a greater interest in the courses for that degree. I thought of graduate school studies, and trying a master of science (MS) degree with a research thesis seemed like a good first step. Southeastern Massachusetts Technological Institute was initiating an MS in chemistry program the summer after I graduated. It seemed like a good fit, and I was supported in this thinking by my soon-to-be wife, Shirley. Shirley could continue her job as a newly graduated Registered Nurse (RN). We married when I graduated in May of 1966.

1.3. MS Degree in Chemistry

Classes providing an advanced preparation in chemistry served me to advantage throughout my career. Professor Dwight L. Baker, my thesis adviser, advised me to visit the Marine Biological Laboratory—Woods Hole Oceanographic Institution Library to research the extensive literature holdings relevant to my research. It was about a 90-min drive away. There were many relevant journal articles! My thesis topic was focused on a specific enzyme in halibut (Farrington & Baker, 1969).

Both Shirley and I wanted to start a family while we were young. Thus, we were very excited on 7 July 1967 by the arrival of our daughter, Karen. Discovering pieces of how the world functions through scientific research is exciting. To my mind, it is second to the privilege of observing a baby, child, and young adult learn about the world!

During a visit to the Marine Biological Laboratory—Woods Hole Oceanographic Institution Library in the fall of 1967, I attended a Woods Hole Oceanographic Institution (WHOI) public seminar. Some of the research was about the chemistry of the ocean. This excited me! Shirley understood and supported my excitement. I applied to oceanography doctor of philosophy (PhD) programs. I was accepted at the Graduate School of Oceanography (GSO), University of Rhode Island, to enroll in the fall of 1968. I finished the last experiments, wrote my MS thesis, and graduated.

We drove to Midland, Michigan, for my summer employment at the Biochemical Research Laboratory of Dow Chemical Company. Research with Dr. Dean Branson was about pioneering insect tissue cell cultures for screening of candidate third-generation pesticide chemicals. The interface of chemistry and biology was a continuing theme in my research interests.

1.4. Graduate School of Oceanography

We drove back to New Bedford at the end of the summer, and soon we had a rental in Rhode Island. Within a week Shirley had a position as an RN working part time 4:00 p.m. to midnight 2–3 days per week and every other weekend. This allowed me to care for Karen while Shirley worked.

I was assigned a Sea Grant graduate assistantship with Assistant Professor James G. Quinn, who had arrived recently at GSO. We sat down to discuss potential research topics. Jim stated (paraphrasing), “I know about lipid chemistry and biochemistry. I think there are a lot of interesting research questions connected with lipids in the marine environment. I do not know much about chemical oceanography and marine
chemistry yet. Perhaps we could learn about that together.” Jim’s enthusiasm and organized approach appealed to me. He was willing to advise me, and I signed on.

Introductory graduate courses in physical, chemical, geological, and biological oceanography were required. Classes were informative and exciting. For example, these were the years of increasing research about plate tectonics. The estuaries class was multidisciplinary: sciences, economics, law, and policy: good preparation for science-policy interface activities.

Another requirement was an ocean research cruise. In August 1969, my office mate, Phil Meyers, and I boarded the R/V Trident, GSO’s research vessel, in Bermuda. A more senior graduate student, Bonnie McGregor, was chief scientist. While underway, each of the scientists took turns for a 4-hr watch for geological survey data. My first watch was miserable. I was sea sick (something that happened to me the first day at sea and lasted about a day throughout my career). We became entangled for a few days in a hurricane. Welcome to oceanography, John! The experience prepared me for research cruises in the future.

The hypothesis of my PhD research was that land plant and animal fatty acids and n-alkanes (straight-chain hydrocarbons), which had a different composition than marine organism fatty acids and hydrocarbons, could be used as tracer proxies for terrigenous organic matter inputs to coastal-estuarine sediments. Narragansett Bay was the study site. We presumed that the Fields Point Sewage Wastewater Plant of Providence, Rhode Island, was a strong source of input of land organism lipids, that is, vegetable oils and animal fats. The effluent discharged into the Providence River, where it flowed into Narragansett Bay.

I applied for and was awarded a Federal Water Quality Administration (soon to be part of the U.S. Environmental Protection Agency, EPA) predoctoral fellowship that supported the remaining two plus years of thesis research.

High concentrations of fatty acids were detected in the sewage effluent because of the presence of partially degraded animal fats and oils and bacteria, as expected. The same fatty acids were also present in the surface sediments of the upper bay samples. The hydrocarbons were another matter. The analyses by gas chromatography of the hydrocarbons in the effluent did not show the expected land plant hydrocarbons. The signal was a mess. We could not figure it out. Those chromatogram strip chart recordings were stored for a few months.

Then, during a visit to the GSO library, I found a published extended abstract that reported gas chromatogram signals similar to ours. The samples were from an uplifted, partially biodegraded petroleum reservoir. It took me only a few minutes to be reasonably certain that I was measuring chronic petroleum inputs that were being discharged from the sewer system. Jim Quinn concurred. One might think “of course.” Hindsight is 20/20. Recently, we wrote a short historical note about this experience (Farrington & Quinn, 2015).

Thus, a significant part of my PhD research focused on chronic oil inputs to Narragansett Bay and subsequent transport and accumulation in surface sediments and hard-shell clams. The other aspect was fatty acid biogeochemistry (Farrington et al., 1973; Farrington & Quinn, 1971a, 1971b, 1973a, 1973b, 1973c). This set a pattern of research throughout my career: biogeochemistry of biogenic organic chemicals and organic chemicals of environmental concern, that is, petroleum chemicals, combustion product polycyclic aromatic hydrocarbons (PAHs), and PCBs. The focus was tracing organic chemical structures through marine ecosystems. Figure 1 provides a simplified version of the biogeochemical cycle of chronic oil inputs in a coastal ecosystem as one example.

Our son, Jeff, was born on 6 December 1970. Shirley, Karen, and I were excited by Jeff’s arrival. Shirley stopped working a bit earlier than we had anticipated to prepare for Jeff’s birth. There was a financial crunch, and I applied for and received a graduate student loan. I worked longer hours in the lab analyzing samples and interpreting data. I was fortunate, and research progressed markedly. Shirley was very supportive and understanding.

During my classes and research, I became aware of publications by pioneers in the field of organic geochemistry. Dr. Max Blumer of WHOI was one of those people. Professor Quinn arranged for us to visit Max. A year later, I applied for a postdoctoral fellowship at WHOI with Max and was fortunate to be selected in the WHOI-wide competition. In addition to continued involvement in marine organic geochemistry research, I would be exposed to Max’s expertise with the powerful analytical method of gas chromatography-mass
spectrometry (GC-MS). Before I arrived, Max secured a National Science Foundation (NSF)-funded postdoc for his lab, and I switched to that postdoc. This change released the WHOI postdoctoral fellowship for someone else.

I submitted my dissertation in early July 1971. The defense was a success. A senior GSO professor told me I had not been in oceanography very long—less than 3 years. He noted I was the first GSO graduate to receive a postdoc at WHOI, something that was news to me. I promised to do my best to not embarrass GSO.

2. Woods Hole Oceanographic Institution

My postdoctoral project focused on biogenic and petroleum hydrocarbons in samples, mostly surface sediments, from the northwestern Atlantic Ocean. Simultaneously, I was writing papers from my PhD research for publication. To my surprise, in mid-1972, I was offered an Assistant Scientist appointment when my first year as a postdoc was finished. I became a member of the Scientific Staff of WHOI, equivalent to tenure track positions in universities. I had traveled around Buzzards Bay to a world of ocean science.

The overarching goal of my research was to advance understanding of biogeochemical cycles of organic chemicals in marine ecosystems (Figure 1). The research focused simultaneously on two threads: the biogeochemistry of (1) biogenic or natural organic chemicals and (2) chemicals of environmental concern. I have organized the following chronologically as snapshots within each thread for ease of understanding. Table 1 provides an outline in a timeline sense of major research undertakings within each thread to assist the reader in following within and between the two threads of the research. In my mind, they were seamless. These efforts were in “Pasteur’s quadrant” as defined by Stokes (1995): driven by interests in both acquiring new fundamental knowledge and addressing societal problems.

I have benefitted from many collaborations with coworkers, students, postdocs, colleagues, and undergraduate students visiting my laboratory and the overall support of staff in various capacities. Several senior colleagues provided valuable mentoring. Mentioning all by name and contribution would take up most of the words allowed for this article. My apology for not doing so. However, I must recognize Bruce Tripp, Alan

Figure 1. Simplified biogeochemical cycle of chronic oil inputs to the coastal environment.
Davis, and Hovey Clifford, research associates in my laboratory, who collectively kept the field sampling and cruises, analyses, and data collection organized for our myriad projects over the years. Nelson Frew provided essential GC-MS skills and advice.

| Table 1 | Timeline of Continuum of John W. Farrington and Laboratory Members’ and Collaborators’ Research 1968–2005 in Outline Format |
|---------|---------------------------------------------------------------------------------------------------------------------------------|
| Professional positions | Research-biogeochemistry of organic chemicals in the marine environment |
| John W. Farrington | Biogenic/natural chemicals | Chemicals of environmental concern |
| PhD dissertation | Narragansett Bay, Rhode Island USA<sup>a</sup> | Chronic oil pollution |
| Research GSO-URI 1968–1917 | Fatty acids | Chronic oil pollution |
| Surface sediments and benthic animals | Western North Atlantic and New York Bight Surface sediments |
| Biogenic hydrocarbons | Chronic oil pollution |
| Postdoc research WHOI 1971–1972 | Surface sediments and marsh sediments | Fate of oil hydrocarbons small spills |
| Assistant Scientist WHOI 1972–1976 | Lipid biomarkers | Surface sediment under Benguela |
| | | Current off Namibia. 1975–1976 |
| | | Lipid biomarkers |
| | | Initiate sediment trap research in situ pump systems for particulates in water column |
| Associate Scientist WHOI 1976–1980 | Lipid biomarkers | Lipid biomarkers |
| | Biogeochemistry of dissolved free amino acids in marine sediments | Lipid biomarkers |
| | PhD dissertation research. | Lipid biomarkers |
| Associate Scientist (with tenure) WHOI 1980–1982 | Biogeochemistry of dissolved free amino acids in marine sediments | PhD dissertation. Susan M. Henrichs, MIT/WHOI. 1975–1980 |
| Senior Scientist WHOI 1983–1988 | Lipid biomarkers in surface sediments and water column particulates of Peru | 1976–1983 U.S. “Mussel Watch” prototype coastal chemical monitoring |
| Director, WHOI Coastal Research Center 1981–1987 | Upwelling area and other diverse oceanic regimes | 1975–1983 Mesocosm experiments: Fates and effects chronic oil inputs |
| | | 1974-2005 PCBs in New Bedford Harbor and Buzzards Bay |
| | Peru upwelling area surface sediments and water column particulate matter | Lipid biomarkers in surface sediments and water column particulates of Peru |
| | Role of colloidal organic matter in the marine geochemistry of PCBs | Sedimentary lipids as indicators of depositional conditions in the coastal Peru upwelling regime |
| | PhD dissertation. Bruce J. Brownawell MIT/WHOI. 1980–1986<sup>b</sup> | Sedimentary lipids as indicators of depositional conditions in the coastal Peru upwelling regime |
| | Sedimentary lipids as indicators of depositional conditions in the coastal Peru upwelling regime | Sedimentary lipids as indicators of depositional conditions in the coastal Peru upwelling regime |
| Michael P. Walsh Professor and Director Environmental Sciences Program, UMass-Boston 1988–1990 | PhD dissertation, Mark A. McCaffrey, MIT/WHOI 1985–1990<sup>c</sup> | Sediment-pore water partitioning of PAHs and PCBs in Boston Harbor, Massachusetts |
| Associate Director for Education, Dean of Graduate Studies 1990–2000. VP Academic Programs and Dean 2002–2005 | PhD dissertation. Susan E. McGroddy, UMass-Boston 1989–1995. | PhD dissertation. Elizabeth B. Kujawinski, MIT/WHOI Joint Program. 1994–2000<sup>d</sup> |

<sup>a</sup>Main focal study geographic areas are in italics.  
<sup>b</sup>Coadvised with Professor Phillip M. Gschwend, MIT.  
<sup>c</sup>Coadvised with Dr. Daniel J. Repeta, WHOI.  
<sup>d</sup>Coadvised with Dr. James W. Moffett, WHOI.
The research was supported by numerous grants and contracts from the Office of Naval Research and NSF in a sustained manner and also from EPA, Sea Grant, the National Oceanic and Atmospheric Administration (NOAA), Department of Energy, and the Outer Continental Shelf Program of the Department of the Interior. Some of the science-policy interactions were supported by grants from private foundations. I had the good fortune of interacting with several first-rate program officers at the federal agencies and foundations.

My research was conducted with samples collected during 18 research cruises for which I was Chief Scientist for eight. They were in open ocean, continental margin, and coastal areas of several countries and U.S. estuarine areas. I was privileged to have one dive in the deep-sea research vehicle Alvin in the summer of 1976. There were numerous 1-day coastal-estuarine sampling cruises and laboratory-scale and mesocosm experiments. A majority of the time was spent analyzing samples in the laboratory and thinking about the resulting data.

When we began this research, much of published literature about specific organic compounds in surface sediments was qualitative in nature. Chemical structures of extracted and isolated compounds were reported. This was important, but we aimed for a quantitative assessment of the presence of the chemicals and the rates of reactions and movement through ecosystems. The success of the research was very much influenced by using the latest advances in analytical chemistry.

Sometimes, results of the research were unexpected. Louis Pasteur’s dictum “Chance favors the prepared mind” came into play. Knowledge hidden away in our minds from both broad and in-depth reading of the literature and attending seminars and scientific meetings was prompted to the fore by the unexpected results. Teaching a graduate course in marine organic geochemistry and leading a seminar in marine geochemistry/chemical oceanography kept me up to date in the field of inquiry as a whole.

These sustained efforts by the entire group have been honored by my election as a fellow of the American Association for the Advancement of Science and American Geophysical Union, among other honors.

3. Biogeochemistry of Naturally Occurring Organic Matter in Sediments and Particulate Matter

I began a collaboration in 1972 with Robert “Bob” B. Gagosian, another assistant scientist in the WHOI Chemistry Department. Bob’s career through postdoctoral research had been chemistry and organic chemistry. Our research interests overlapped, and our experiences were complementary. Bob’s research focused initially on the biogeochemistry of sterols in the water column. We had collaborative cruises in the northwestern Atlantic.

The Benguela Current area off the coast of South Africa and Namibia, an area with very high primary production and an area of diatomaceous surface sediment with a high amount of 20% organic carbon, attracted our attention. The input was mainly marine organic matter, in contrast to mixed terrigenous and marine organic matter input to the northwestern Atlantic sediments. A cruise from Woods Hole into the Indian Ocean was shaping up, and we were able to secure funding for our research and the needed ship time for our sampling plan. Our leg of the cruise, R/V Atlantis II 93/3, traversed from Cape Town up the continental margin off Namibia into outer Walvis Bay and back to Cape Town, South Africa. I was chief scientist and thus responsible for cruise planning, scientific operations at sea, and interacting with the ship’s agent to ship our gear and samples back to Woods Hole.

We loaded equipment and supplies on the ship in Woods Hole. Two months later, we joined the ship in Cape Town on 20 December 1975 after a flight that unexpectedly had to dodge the erupting Angolan Civil War. We were at sea for Christmas and New Year’s, departing 22 December 1975 and returning to Cape Town on 8 January 1976. The cruise was a success, with many samples and myriad data collected.

The frozen sediment samples from the cruise arrived at Woods Hole, and we began analyses. Nelson Frew, a research associate in our department, had initiated a GC-MS-computer facility. Nelson’s facility, expertise, and advice were an essential factor in the success of my research for several decades. While demonstrating GC-MS analysis data output to undergraduate summer employee Dan Repeta (now a WHOI Senior Scientist), we serendipitously discovered the presence of cholestadiene (a reaction product of cholesterol)
in the surface sediments. This led to exciting research unraveling the early stages of diagenesis of sterols in surface sediments (Gagosian & Farrington, 1978).

Back in the northwestern Atlantic, reports by biology colleagues of “fluffy surface floc” at the sediment-water interface on the continental slope areas observed from deep-sea research vehicle Alvin piqued my interest. An NSF grant in collaboration with several colleagues led to my only dive in Alvin in July of 1976 to obtain a carefully collected small box core with Alvin’s manipulator arm. Our objective was to capture the surface floc—most likely freshly deposited within months or less from the overlying water column. On the way to the bottom (1,500 m), the view out of the porthole astonished me with the various layers of jellylike organisms and mucous-like material suspended in the water at various depths below the euphotic zone. I had read and heard about this “marine snow,” first described by William Beebe from his Bathysphere dive and written about by Rachel Carson in “The Sea Around Us” (LaCapra, 2019). Seeing it first hand was an “Aha moment!” Clearly, much more biogeochemistry was happening in the water column than we had been thinking on the basis of analyses of samples obtained using the accepted water sampling and glass fiber filtration protocols to isolate particulate matter.

I did not obtain the box core because of gear malfunctions. Later that summer Susan Henrichs, my first Massachusetts Institute of Technology (MIT)/WHOI Joint Program graduate student advisee (1975–1980), obtained the requisite cores and excellent photographs of the operation documenting that we had a sample of the surface floc. Cindy Lee, a postdoctoral researcher supported by Bob Gagosian and me, analyzed the floc and underlying sediments for sterol compositions and compared them to other data of northwestern Atlantic open ocean and coastal sediments. The paper reporting the results and interpretation (Lee et al., 1979) received the 1979 Best Paper Award of the Organic Geochemistry Division of the Geochemical Society.

These observations from Alvin led to many years of obtaining sediment trap/particle interceptor trap and large in situ pump samples, analyses, and data interpretation. The first sediment trap samples came from WHOI colleague Susumu “Sus” Honjo, a pioneer in open ocean sediment trap research. Sus called me one day and asked if I could assist in “getting rid of organic matter” in some of his trap sample splits so he could analyze the minerals. I told him I would help if I could keep the organic matter for analysis! I extracted the samples, giving back the minerals, and refrigerated the extracts. Stuart Wakeham arrived as an Assistant Scientist shortly thereafter and analyzed these extracts. This led to many years of productive research in our labs and elsewhere, unraveling the details of the biogeochemical cycles of organic matter in the coastal and oceanic water columns and surface sediments, mainly researching specific lipid compounds. Collaborations with Bob Gagosian, Cindy Lee (now on the WHOI Scientific Staff), Stuart Wakeham, postdoc and, later, visiting scientist John Volkman, WHOI research assistants and associates, and students were essential to these efforts (e.g., Lee et al., 1983; Volkman et al., 1987; Wakeham et al., 1980, 1983, 1984).

Susan Henrich’s PhD research focused on the biogeochemistry of amino acids in surface sediment and pore water, another aspect of the carbon (and nitrogen) cycle. The pore water analyses provided unique insights. Susan and I benefitted from the fact that Cindy Lee, a member of Susan’s committee, had completed her PhD dissertation at Scripps Institution of Oceanography, focused on amino acids in seawater. We secured an NSF grant supporting Susan’s research. Sediment cores were obtained from the northwestern Atlantic and the Peru continental margin. The latter was another upwelling area with organic-rich surface sediments. Susan’s research provided significant understanding of the carbon and nitrogen cycle during early diagenesis (Henrichs et al., 1984; Henrichs & Farrington, 1979, 1980, 1984).

The Peru cruise (R/V Knorr 72-3) was memorable for the transit from Panama to Peru, during which we crossed the equator, converting several of us from pollywogs to crusty shellbacks.

I had learned the importance of obtaining samples from key distant locations for future analyses. Subsamples of Susan’s Peru cores were stored frozen. During that same Peru cruise, we obtained splits of floating sediment trap samples from MIT/WHOI biological oceanography graduate student Nick Staresinic, who had designed the traps for his studies of carbon flux through that ecosystem (Staresinic et al., 1983). These samples provided for some of the first analyses of lipid-class compounds in large particles from an upwelling area coupled with analyses of underlying surface sediments (e.g., Volkman et al., 1983; Wakeham et al., 1983).
The mid-1980s departure of Cindy Lee to the State University of New York at Stony Brook and Stuart Wakeham to Skidaway Institute of Oceanography was a major disappointment for me. I thought WHOI should have done more to keep them. Bob Gagosian was now more involved in administrative leadership at WHOI. It was a midcareer crisis to experience the breakup of this team of WHOI colleagues. I decided to pursue another appointment and was fortunate to receive an appointment as Michael P. Walsh Professor of Environmental Sciences at the University of Massachusetts Boston (1987) while keeping an adjunct appointment and small lab at WHOI.

We secured an NSF grant to analyze the lipids in the frozen Peru sediment subsamples and to ascertain if we could discern El Niño–Southern Oscillation records with a set of new cores of the surface sediment collected during a cruise in 1987, R/V Moana Wave 87-08. The El Niño–Southern Oscillation record effort was only partially a success because the deposition rates of sediments were too low to record individual years, even with 2- to 3-mm slices of sediment possible at that time. However, the detailed analyses of many lipid compounds in these organic-rich surface sediments advanced our understanding of the early diagenesis of organic matter. These efforts were mainly the PhD dissertation of MIT/WHOI Joint Program student Mark McCaffrey (e.g., McCaffrey et al., 1990, 1991).

One enduring memory for me, as Chief Scientist of the cruise, was unloading our gear and samples in Callao, the port city for Lima, and moving to our Lima hotel in the midst of the Sendero Luminoso guerrilla activity. There were explosions and gunfire near our locations!

4. Biogeochemistry of Organic Chemicals of Environmental Concern

Returning to the 1972–1976 times, we documented extensive chronic petroleum hydrocarbon pollution and contamination in New York Bight surface sediments from disposal of sewage sludge and harbor dredge spoils in the bight. There was also extension of that contamination to surface sediments of the continental margin Hudson River Trough and Canyon (Farrington & Tripp, 1977). We used cores of sediments to assess historical records of oil contamination and PAHs from fossil fuel combustion products in sediments. The latter was in collaboration with Professor Ronald Hites, then, at MIT, now at Indiana University. (Farrington et al., 1977; Hites et al., 1977, 1980). PAHs were of concern because of adverse effects on marine organisms at certain concentrations, and some were known or suspected carcinogens.

Earlier, Max Blumer, Howard Sanders, John Teal, and their laboratories were involved in pioneering studies of the West Falmouth oil spill (WFOS) of September 1969. In October of 1974, another barge spilled No. 2 fuel oil a few kilometers up the coast from the WFOS site. Max Blumer was disengaging from oil spill studies and focusing his research on combustion-derived PAHs. My lab entered the fray. Fortunately, John Teal of the WHOI Biology Department became a career-long mentor at this time. We documented the presence and longevity of fuel oil hydrocarbons in some of the marsh sediments, as reported for WFOS (Teal et al., 1978. The past 40+ years of literature show these were not isolated cases (e.g., Farrington, 2014). We conducted research on two other small fuel oil spills during the 1970s–1980s in Buzzards Bay to gain a better understanding of the uptake and release of petroleum hydrocarbons by local mussel populations (e.g., Farrington et al., 1986).

In the same time period, we became involved in mesocosm experiments using 21,000-L cylindrical tanks with 30 cm of sediment at the bottom. This was a multi-investigator project based at the GSO-University of Rhode Island Marine Ecosystems Research Laboratory designed to approximate the mid-Narragansett Bay ecosystem. The focal project was chronic oil exposure at concentrations found in coastal-estuarine harbor areas. Our research focused on the fate of PAHs in these systems, including an experiment using a specific PAH, $^{14}$C-labeled benz[a]anthracene (e.g., Farrington et al., 1982; Hinga et al., 1980).

Simultaneously, in 1974–1975, I was recruited by Professor Edward Goldberg of Scripps Institution of Oceanography to join a group to prototype, with funding from EPA, a monitoring system for chemicals of environmental concern around the coast of the continental United States using mussels and oysters as sentinel organisms. My lab focused on petroleum hydrocarbons, PAHs and PCBs, and DDT compounds. Two other labs were involved in analyzing the same chemicals. Other labs analyzed selected trace metals and $^{137}$Cs and $^{239,240}$Pu. This involved analyses of mussels or oysters from about 100 stations around the U.S. coast repeated annually for 3 years: the Mussel Watch. The prototype was a success. It led to the NOAA
Status and Trends Program that was several decades in duration and other international efforts (e.g., see Goldberg et al., 1978; Farrington et al., 1983, 2016).

During 1973, analyses of surface sediments from the outer New Bedford Harbor for PAHs by Dr. Walter Giger, a visiting scientist in Blumer's lab, revealed high concentrations of PCBs as coisolates of the PAHs. As someone who grew up in New Bedford, I was asked why that might be. My answer was as follows: New Bedford was home to two of the largest PCB-containing capacitor manufacturing plants in the United States. Both facilities were located on the harbor’s edge. It would have been unusual in those times if there had been no leakage of PCBs.

Surely, I thought, someone was looking into this because environmental concerns about PCBs were well known. There had been a few survey reports, but not much was happening as follow-up. Interactions with two PCB experts, Bob Risebrough, a California colleague from the Mussel Watch activities, and Ian Nisbett, the science director of the Massachusetts Audubon Society, provided some additional information. My lab began an investigation that grew into a major undertaking during the late 1970s through the mid-1980s. We documented very high concentrations of PCBs in sediments, water, and organisms of the inner and outer harbor using high-resolution analyses demonstrating that the composition of PCBs changed as they entered the food web. The PCB input had stopped, but there was a large amount in sediments. Our research and dogged communications with Massachusetts agencies and elected officials (e.g., Farrington et al., 1985; Farrington et al., 1986) contributed to this area becoming an EPA Superfund site. Eventually, all our data files and correspondence were subpoenaed in a U.S. federal court case concerned with this matter.

It was during this same period of time that I became involved in planning and bringing online, with other colleagues, WHOI’s Coastal Research Center, which served as a focal point for interdisciplinary coastal research at WHOI until 2017. Judy McDowell of the Biology Department became a close colleague at this time fostering several productive discussions and research efforts.

Bruce Brownawell, a MIT/WHOI Joint Program graduate student, arrived in 1980. He had a strong interest in the biogeochemistry of organic chemicals of environmental concern. Noting Susan Henrich’s pore water research, he posited that PCBs in pore waters of sediments and their interactions with organic colloids might be key to their flux to the overlying water column and their bioavailability. His PhD research, coadvised by Professor Phil Gschwend (MIT) and me, was pioneering and contributed much fundamental knowledge for key aspects of the New Bedford Harbor Superfund assessment (e.g., Brownawell & Farrington, 1985, 1986).

I was serving on Anne McElroy’s dissertation committee (John Teal was the major adviser) during that same time. Anne’s research focused on the bioavailability of PAHs from various sources, for example, combustion particles and PAHs from petroleum sorbed to sediment particles (McElroy et al., 1989, 1990). Anne’s and Bruce’s research led to the University of Massachusetts Boston PhD research of Susan McGroddy, focused on partitioning of PAHs from various sources in Boston Harbor sediments (McGroddy et al., 1996; McGroddy & Farrington, 1995). The results demonstrated that one could not simply measure concentrations of individual PAHs in bulk sediment samples and then calculate bioconcentration factors in bottom-living organisms, as had been proposed by regulatory authorities.

I moved back to WHOI in August of 1990 as dean of graduate studies and associate director for education. Susan McGroddy came with me as a guest student to complete her PhD research. Assistant Professor Hideshige Takada arrived at the same time from the Tokyo University of Agriculture and Technology for a several-month visit. He participated in a project investigating the fate of New York sewage sludge disposed in surface waters at Deep Water Dumpsite 106 on the northwestern Atlantic continental slope at 2,400- to 2,900-m water depths. Dispersion and extensive biodegradation in the water column were expected to render this site a safe place of disposal. Our research, with the U.S. Geological Survey and other colleagues, documented that substantial concentrations of organic chemicals in the sludge and other sludge indicators were being deposited at the sediment-water interface (Bothner et al., 1994; Takada et al., 1994). The disposal was stopped after a few years.

Elizabeth “Liz” Kujawinski, an MIT/WHOI Joint Program student, coadvised by Jim Moffett and me, noted the importance of dissolved organic matter interactions with PCBs and PAHs in the research discussed above and in research published by others. She conducted elegant laboratory experiments demonstrating the importance of surface-active organic matter produced during protozoan grazing on bacteria and the
high affinity of the organic matter for PCBs (Kujawinski et al., 2000, 2001, 2002). Liz was the last PhD student I advised in a formal sense.

In summary, I believe the above research yielded important details of the biogeochemistry and bioavailability of PAHs and PCBs in marine ecosystems.

5. Science-Policy Interface

I kept my self-promise to do my duty as a citizen scientist. I had learned from the experiences of Max Blumer and WHOI biologist and benthic ecologist Howard Sanders as they discussed the findings of their pioneering WFOS studies with elected and appointed officials and with the general public. Their essential message was the spilled oil did not disappear from the environment simply because the visible oil slick was gone. Some of the oil chemicals persisted for several years, as did several biological effects.

Many in the petroleum industry tried to discredit the WFOS studies or note that this was an isolated case. Certainly, several areas recovered after years. However, follow-on research documented that in some marsh areas some oil chemicals persisted for decades along with several sublethal effects. Believing he had done what he could, Max turned to other research and then was lost tragically to cancer (Farrington, 1978). Increasingly, after 1973, I became the WHOI “expert” biogeochemist in oil pollution matters and remained so until the mid-1990s when Dr. Christopher Reddy took on that mantle. I have the impression that I was on “the bad list” of the American Petroleum Institute during this time even though I had several cordial and productive discussions with researchers in the petroleum industry.

Participation in the 1979 NOAA Ship Researcher cruise to the IXTOC-I oil well blowout provided key lessons about planning, sampling, and follow-up research for large oil spills. Unfortunately, there was the oft-repeated lesson of curtailment of funding once the spill fell out of the news cycle (Farrington, 1983, 2010a).

Participation in the 1975 National Academy of Sciences study Petroleum in the Marine Environment (National Research Council, 1975) as section writer and workshop attendee led to being a steering committee member of the National Academy of Sciences Oil in the Sea report (National Research Council, 1985) and a reviewer for the Oil in the Sea III study (Transportation Research Board and National Research Council, 2003). I have served on several other U.S. National Research Council committees. One committee I chaired focused on Outer Continental Shelf Environmental Studies and issued five reports, one of which was to a cabinet-level task force reporting to President George H. W. Bush.

Testifying before committees of the U.S. Congress about marine environmental quality provided a glimpse of the U.S. legislative process. Equally important in my view is educating the public. Throughout my career, I have given talks and written articles for the general public (e.g., Farrington, 1977; Farrington, 1985; Farrington et al., 1982; Farrington & McDowell, 2004).

An early foray into international science-policy interactions was my participation in an exchange visit involving 10 days in the USSR in September 1975 as part of the efforts of the US-USSR Joint Working Group on the Effects of Marine Pollution. There were visits to universities and institutes in Moscow, Sevastopol (via Yalta), and Leningrad (St. Petersburg). One highlight in St. Petersburg was a visit to the Mendeleev Museum to view pages of the periodic table notebooks! I maintained professional contacts for decades with scientists I met.

Involvement in the International Council for the Exploration of the Seas and the Intergovernmental Oceanographic Commission-United Nations Educational, Scientific and Cultural Organization committees brought the environmental quality research done by my lab into the international science-policy arena. As chair of the U.S. National Committee for the International Council for Science's Scientific Committee on Problems of the Environment (SCOPE) from 1983 to 1986, I attended a meeting in Delhi, India, during which there was a workshop pertaining to the SCOPE Study of the Environmental Consequences of Nuclear Warfare. The U.S. National Committee arranged for the U.S. National Academies to host the 1985 SCOPE General Assembly, at which the Environmental Consequences of Nuclear Warfare report was presented. These sobering activities taught me valuable lessons, even though my role was in the background.

An interaction of a different type was an opportunity presented by a private foundation to coordinate the WHOI side of a memorandum of understanding with the University of Concepción in Chile to expand the
ocean sciences research and education at that university. The multiyear program infused millions of U.S. dollars from the Chilean private foundation that catalyzed very productive research and education.

Yet another type of interaction focused on religion, science, and the environment. Scientific facts are often insufficient to convince people to change the way they live to protect the environment. Most people are inspired significantly or in part by their religion and beliefs. Most of the world’s religions and belief structures call for good stewardship of the environment (Hobson & Lubchenco, 1997). I participated in a symposium cruise to seven ports around the Black Sea in 1997 with several hundred individuals: religious and belief leaders, scientists, nongovernmental organization leaders, European business leaders, and media individuals (Hobson & Mee, 1998). It was an inspiring experience. I have presented several seminars based on that experience and even delivered a “sermon” (Farrington, 2010b).

Since 2010, at the invitation of Dr. Rita Colwell, I have been a member of the research board she chairs that oversees the independent Gulf of Mexico Research Initiative funded at $500 million for 10 years by BP following the Deepwater Horizon oil well blowout disaster. My contributions to this effort have been informed by the research and experience at the science-policy interface described herein.

My advice concerning activities at the science-policy interface is to bring a wide range of activities to the interface and to be patient and persistent. Above all else, as advised by John Adams, “Let us dare to read, think, speak and write.”

6. Dean at WHOI

I had the pleasure of being dean at WHOI for 15 years, during which I interacted with exceptional graduate students in the MIT/WHOI Joint Program in concert with MIT faculty and WHOI scientific staff. I had wonderful interactions with WHOI’s highly regarded postdocs through oversight of the Postdoctoral Scholar Program.

I have been active in various ways throughout my career, including involvement with professional organizations (e.g., Holmes et al., 2011), to advance gender equity. Likewise, I devoted considerable time to the issues of greater overall diversity in ocean sciences and geosciences (e.g., the Woods Hole Diversity Initiative). Much remains to be done in both arenas.

I plan to write more in detail about these important experiences in another venue.

7. Concluding Comments

After 15 rewarding years as dean, I stepped aside in November 2005 and retired from WHOI in March 2006. I have kept active in various capacities in part-time and interim positions and advisory committees. My wife Shirley has noted to some friends that I have “flunked retirement at least four times.”

This paper is dedicated to my wife Shirley in appreciation for all she has done to bring happiness to my life. I am working on a memoir dedicated to our two children, four grandchildren, and a great granddaughter.

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