NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
VOICES ORAL HISTORY ARCHIVES

IN PARTNERSHIP WITH
NOAA HERITAGE AND THE NATIONAL WEATHER SERVICE

AN INTERVIEW WITH
DR. RICHARD FEELY

FOR THE
NOAA 50th ORAL HISTORY PROJECT

INTERVIEW CONDUCTED BY
MOLLY GRAHAM

LYNWOOD, WASHINGTON
JANUARY 29, 2021

TRANSCRIPT BY
MOLLY GRAHAM

Molly Graham: This begins an oral history interview with Dr. Richard Feely for the NOAA 50th Oral History Project. Today's date is January 29, 2021. The interviewer is Molly Graham. It's a remote interview with Dr. Feely in Lynnwood, Washington. I'm in Scarborough, Maine. Where we left off last time was with your decision between leading the Carbon Programs or the Vent Program. Eddie Bernard advised you to follow your heart, and your heart was with the Carbon Program. Could you talk a little bit about that time period and the impetus for starting this program in the first place?

Richard Feely: Yes. Well, actually, working on carbon started in the early 1980s. NOAA [National Oceanic and Atmospheric Administration] was just getting started with atmospheric measurements. We worked with Lester Machta, who was the head of the NOAA Air Resources Laboratory at that time. He was a great visionary. He really wanted to see NOAA have not only an atmospheric carbon program but a marine carbon program as well. So we got together with him, and he provided some funds to PMEL. We started working on ocean carbon in the early '80s. Our first cruise was around 1981. What we did at that time was learn how to do the techniques because the techniques were not well determined yet. So on a couple of first cruises, we went out just to learn how to measure the DIC [dissolved inorganic carbon] and the total alkalinity and the major carbon parameters. At that time, it was so early on that there were no standards, so we had to prepare our own standards. We really had to teach ourselves how to make the carbon measurements. But we did that, and we formed a little group, a very small group: myself, Joe Kline, and our technicians at that time. We taught ourselves. We got a lot of help from Arthur Chen from Oregon State University, who helped train us on this. So that moved along to the point where we had to write a NOAA carbon plan, both atmospheric and ocean. Pieter Tans and I, and Don Atwood, who was the leader of the ocean carbon group in AOML [Atlantic Oceanographic and Meteorological Laboratory], got together, and we worked with Jim Todd, who was the program manager at that time for carbon in the Climate Change Program Office. We all got together, and we began working on developing a carbon plan. In doing so, we realized that this was going to be too big for NOAA alone. So what we had to do is to work together with the National Science Foundation as well. So Mike Hall, who was the director of the Office of Global Programs at that time, suggested that I contact Peter Brewer. Peter Brewer was from the Woods Hole Oceanographic Institution, a person I'd known quite well for many years. He was leading the JGOFS [Joint Global Ocean Flux Study] program, which was just getting started at that time. There was also the WOCE [World Ocean Circulation Experiment] Hydrographic Program [WHP]. The idea was to see if we could meld together the WOCE hydrographic program, the US JGOFS program, and NOAA's Ocean Carbon Program. I met with Peter Brewer in Woods Hole. Again, we've known each other for a long time. We began to sit down and think about how we could do this. This was the time when we were writing the strategic plans for NOAA, and the US JGOFS, and the WOCE hydrographic program. It seemed that it could fit together if we could make the carbon measurements globally on the WOCE hydrographic cruises and that when there were process studies under JGOFS, then we could make the carbon measurements on those process studies as well. The problem was that, at that time, the NOAA component of that, particularly from the marine side, was very small; it was just me. On the Atlantic side, Don Atwood was taking the lead on that, and he realized he had to hire somebody to take the lead on that end. So we got together and worked it out. Rik Wanninkhof, who was just getting his PhD at Lamont Doherty Earth Observatory under Taro Takahashi, came aboard, and moved to Miami. That represented the Atlantic side. My group represented the

Pacific side. Rik and I together worked out the cruises for the Indian Ocean. Between the two laboratories, we were able to devise a plan that would cover all three ocean basins as part of the WOCE Hydrographic program, working with the National Science Foundation and the carbon chemists from the National Science Foundation, which was supported by NSF and the Department of Energy [DOE] at that time. Doug Wallace, representing the Department of Energy, was leading that effort and the National Science Foundation. We brought in about six or seven groups of carbon chemists to provide the measurements from the US side. At the same time, at the International level, we were working with the international community to do the same thing with the international cruises. The WOCE Hydrographic Program was a ten-year effort in the late 1980s and early 1990s. There were some hundred cruises and a hundred-thousand samples that were collected. We were off and running. We were able to have this international program. We were making carbon measurements that were essentially not the first carbon measurements because Peter Brewer and colleagues did the first carbon measurements as part of GeoSecs Program. But it was the largest survey of carbon that was ever attempted, and it was extremely successful. We did a fantastic job. We developed the new measurements of the total carbon at that time, and that was in place. Andrew Dickson took the leadership along with Dave Keeling on developing carbon standards for the community. We had a good set of carbon standards. We had a really great set of cruises that the entire ocean carbon community was behind. We were doing that at the same time the process studies in US JGOFS and international JGOFS were underway. We were invited to participate in that process study as well. In fact, we played a major role in the Equatorial Pacific

Process Study that was conducted all the way across the Equatorial Pacific in 1992. We played a major role in that as well, with many, many NOAA cruises contributing to that. We had some wonderful cruises there. I was chief scientist on a number of them, and we saved a few lives along the way. By chance, we saved a guy who was sitting on top of his overturned sailboat. If we didn't just come along, he would have died. We had some incredible opportunities to do some amazing things at sea.

MG: Well, tell me a little bit more about that.

RF: Yes. This was a person who sold his house, and he was a US citizen. He sold his house, and his big idea was to sail from Tahiti to Hawaii. He bought a sailboat, and he and his cat got on the sailboat. We were sailing across the equator at the time. Actually, it was on Good Friday in 1992. We were called to see if we could do a search and rescue. We had to divert the cruise and go find this gentleman.

We found him on Holy Saturday evening. I was sitting there with the captain of the ship as we were approaching him, and he was sitting on top of his overturned vessel with his life jacket on. He had been sitting overnight and all day. He was totally sunburned and just barely surviving. We came and were able to pick him up. He asked about his vessel, and they said, "As soon as we lift that out of the water, it's going to break up because you already have an enormous hole in it." He had hit a submerged buoy in the middle of the night, and his sailboat turned over on him right away. He was able to get the beacon out so that he called a distress call. The Coast Guard picked it up and asked us to go pick him up. We did that. I can remember the exact conversation that we had. He was a delightful man. We brought him onboard the ship. He stayed with us for the rest of the cruise. He had nothing, so we provided him with clothes and food. Everybody was very wonderful to him. He was a very wonderful, outgoing person, a delightful person. Later on, he wrote a book about the event. I have a copy of his book about his adventure at sea on his very first cruise. I'm very happy to provide that opportunity to save his life. I had to argue to get more ship days to finish our work, which the admiral provided for us. We were ver fortunate. We got all of our work done. It was quite an exciting time.

MG: Was this cruise on a NOAA Corps ship?

RF: Yes, we were on the NOAA research ship *Discover*, which is the primary ship for the Pacific for large-scale cruises like this. One of our cruises in the Western Pacific was a long one, 160 [degrees] West. They were going from Tahiti to Hawaii, and we were doing a survey along that line. It took us about half a day to go find him and collect them.

MG: What an incredible story. This took place at a time when the NOAA Corps was potentially going to be eliminated, so it must have helped to show that not only do these vessels help with research, but they save lives.

RF: Our first and foremost obligation was to make sure that we rescued people when that situation came up. This was a US citizen, so that made it even more important. We were happy to do that. There were other incidences that we had where we were very proud to contribute in any way we could.

MG: There are a couple of things I want to ask you about during this time period because, really, you're on the precipice of a lot of changes when it comes to research on carbon in the ocean. For a long time, scientists knew it existed, but it wasn't until the '80s, where they began to measure the impact. Can you talk about those first signs or when the research shifted?

RF: Yes. As chemical oceanographers, I will say that even in graduate school, in the late '60s and '70s, we knew about the carbon issue. It was taught in graduate school, and I was a very young man at the time. Carbon was a major part of my life, even from graduate school onward. I was very excited to actually have the opportunity to develop that capability in our laboratory. Again, that was the leadership of Lester Machta, saying this would be a good thing and getting good support to do that. We began those cruises with a very tiny amount of support.
But we took advantage of it because we had a large amount of ship time at the time. We started out these initial cruises with just support from NOAA. Our goal was to see if we could distinguish the difference between the anthropogenic carbon signal, the mankind signal in the oceans, and the distribution of carbon that already exists in the oceans. The oceans are the largest repository for carbon dioxide, with the exception of ocean sediments, on Earth. The oceans have a very high concentration of carbon dioxide naturally. The trick was to be able to measure carbon so well, so precisely and accurately, that we were able to distinguish the anthropogenic carbon from the natural carbon. That anthropogenic signal was small. You had to have very good measurements. What we had to learn over those early years is how to make those measurements very precisely and accurately, with great detail on the accuracy of our measurements and proper standards. But this community came together to do that. The carbon issue was a major issue politically back in the '70s and '80s, as well. There was a strong need to understand the

inventories of carbon in the atmosphere and the oceans. My colleagues Richard Gammon and Pieter Tans, who directed the carbon laboratory [Global Monitoring Laboratory] in Boulder under ESRL [Earth System Research Laboratories], worked very closely with us. They would have their scientists onboard our cruises. They were collecting atmospheric samples. We were collecting atmospheric samples as well as surface to bottom ocean samples. We were absolutely adamant that we had to measure surface to bottom because what we really wanted to know is where that carbon was going, how it was being taken up across the air-sea interface, and where it was going. The circulation was being determined by the world hydrographic programs so that that was being covered that way. We were collecting the carbon measurements on all of those cruises, so we could actually determine the anthropogenic carbon. But that had not been done before. Part of the effort was to develop those techniques to determine the anthropogenic carbon. We had a very good colleague at the time, Nicki [Nicolas] Gruber, who was working with Jorge Sarmiento at Princeton University. He developed a technique which was a derivation of an earlier technique by Arthur Chen, to separate out the anthropogenic carbon signal from all the natural carbon processes. We could do that because we had the chemical tracers as well, which allowed us to trace the age of the water mass. That allowed us then to track the changes in carbon relative to those water masses itself. Because we can track those changes in carbon, we could delineate the anthropogenic carbon signal. We also used some work that Paul Quay from the University of Washington developed to use the carbon isotopes, carbon 13, carbon 12 isotopes to delineate the anthropogenic signal. That's because the carbon 13 signal is unique in the anthropogenic component of that. We could trace that unique carbon 13 signal as well as determine the anthropogenic carbon. That allowed us to isolate that anthropogenic signal. We did that on all the cruises, and everything agreed quite well. Chris Sabine, who was working with me at that time – in the late 1980s and 90s, we worked together. He was at Princeton at the time early on. Then, later on, he joined me at PMEL [Pacific Marine Environmental Laboratory]. Together we worked on the distribution of anthropogenic carbon for the global oceans. When we published that paper in *Science* in 2004, it was the culmination of all these hundreds of thousands of data points from the WOCE Hydrographic Program cruises. That was the first time ever that we had a global picture of anthropogenic carbon in the oceans. We did that with the help of Nicki Gruber and others and Rik Wanninkhof. We published that in *Science*. Now, what made that so special is that, at the same time and in that same issue, in back to back papers, I was able to publish the impact of that anthropogenic carbon in terms of the changing carbonate chemistry in the water column and its effects on the biology. So what we did is we published the anthropogenic carbon distributions in one paper and those very important chemical and biological impacts in a companion paper, back- to-back papers. Our chances of getting those papers published in *Science*, two back-to-back papers was less than one percent. But it was so important. The editors of *Science* realized how important it was. They made an exception for us to publish these two papers back-to-back in 2004. That really helped us motivate both the Carbon Program as well as the Ocean Acidification Program. The Ocean Acidification Program did not exist at that time at NOAA. So, because we are able to publish these two papers in *Science* and get a cover picture on the cover of *Science* about the biological impact on the pteropods – we got that on the cover of *Science*. That's what made many of the scientists in the United States stand up and take notice. From there, we were able to convince NOAA headquarters that this was an important issue for them. Ultimately, we were able to develop the NOAA Ocean Acidification Program that was very collaborative and back-to-back with the Carbon Program. So everything we did in carbon, we made sure we were making the ocean acidification measurements as well as the pH measurements and other measurements from that point onward. Together, we provided the kind of global information to understand not only the global carbon cycle, not only the distribution and transport of anthropogenic carbon but the impact on ocean acidification. They all came together. To this day, they still work hand in glove. The NOAA GOMO [Global Ocean Monitoring and Observing] Program office works very closely with the NOAA Ocean Acidification Program. Together, we create this global picture of the changes in anthropogenic carbon and its impacts on ocean acidification. So it all started with a group of scientists that were very interested to understand how anthropogenic carbon is distributed between the atmosphere and the oceans and what those biological and biogeochemical impacts are. We were able to work with our colleagues in the National Science Foundation and Department of Energy and our international colleagues through the International Ocean Carbon Coordination Project, IOCCP, and later on, the GOA- ON, Global Ocean Acidification Observing Network, to work together internationally to put all these programs together and make them work. Right now, we are left with the international GO-SHIP [Global Ocean Ship-based Hydrographic Investigations Program] program and the international [Global] Ocean Acidification Observing Network, all working together to provide these measurements to this date. It's now in its fourth decade. It's quite amazing what we've been able to accomplish.

MG: Can you speak a little bit more about the impacts on the marine organisms and the coral reef?

RF: Yes. This was quite an exciting area of research. There is a wonderful story. In 1999, I went up to the library one day, and I pulled out a copy of *Science*. I always check *Science* once a week. I pulled out a copy of *Science*, and the cover story was the impact of ocean acidification on coral reefs led by a very dear friend of mine, Joan Kleypas, and she was working at NCAR in Boulder at the time. I had not met her before, but the article was so impressive to me that I called her up that day. I said, "Joanie, I know you don't know me." "Oh, sure. I know all about you." "Okay, that's good. I just love your paper. I read it today. I love your paper because I think it's really important. What you're laying out here is this impact of ocean acidification on coral reefs. The reason why I'm calling you is because I think that we should expand this and address it as not just for coral reefs but for entire oceans and ocean impacts. We are working on this global perspective that I don't think we'll have done for another five years. But what I would like to ask you is if you would join me in writing a paper on this global perspective when we have that data set ready five years from now." She said, "Oh, thank you very much. I would love to do that. I really think this is an important issue. My whole expertise is in the coral reefs, but I would love to think of it from a much larger perspective." I said, "Okay. Well, I'll ask the same question to my dear colleague, Vicky [Victoria] Fabry from the University of California San Marcos, and she's an expert on biological impacts of ocean acidification on marine pteropods. They are a global species. If we could get you two to lead that effort, and then myself and the rest of my chemists will lead the chemistry efforts, and then we can pull this all together. Who knows, we might even get a paper in *Science* on that." Over those five years, we got together quite a bit and talked about that. As we were developing these two perspectives on the distribution of anthropogenic CO_2, I had in mind for Chris Sabine and Rik Wanninkhof and others to lead that part of it, that paper because I had in mind to lead the paper on the impacts on the biology. I knew if we could put those two papers out together, that it would have an incredible impact. I really wanted to see these be impactful papers. So we had the right people lined up to write these papers. Actually, the writing of both papers went simultaneously and went quite well. We were ready to submit them, and we submitted them together. This is something – but I had Joanie Kleypas to address the coral reef issues. I had Vicky Fabry address the impacts on the pelagic biology so we could address all of these biological implications. Well, Vicky had been working with me since the early 1980s on the impacts of CO_2 on pteropods. She had done some work on our cruises that showed that they were being impacted right now in ways nobody really had seen before. This is the effect of the corrosive waters by the addition of anthropogenic CO_2 in the North Pacific, where the corrosive waters got very close to the surface. Sure enough, she could see the dissolution of those pteropods. When we wrote that paper in *Science*, we asked the editors if we could put her pteropods on the cover. She had a beautiful pteropod on the cover. We wrote the story. We showed the impact of the dissolution occurring in the water column. We were able to calculate those dissolution processes, and so it was extremely impactful. At the same time, we were able to relate that to the coral reefs as well. When we actually published that paper in 2004, I think there was somewhere in the neighborhood of between one hundred and fifty and two hundred newspapers that took those articles and ran with them. We had a tremendous impact. Certainly, the largest impact I've ever had in my career was based on those two papers, and that really got NOAA excited. It certainly got the National Science Foundation excited. Our colleagues in Europe, led by Jean-Pierre Gattuso and Ulf Riebesell, had been doing the same kind of work in Europe. Jean-Pierre Gattuso had been working in coral regions. Ulf Riebesell was a pelagic biologist. They had been doing exactly the same kind of work there. We immediately got in contact with them. They were starting the EPOCA [European Project on Ocean Acidification] program, which was just getting started at that time. We developed this international collaboration between the US, Europe, and my colleague Bronte Tilbrook was doing the same thing in Australia. We linked him in, and so now we were getting many, many countries involved. We are all working together. Jean-Pierre led that effort in Europe and asked us to participate in their planning activities, and we did. So now we had a companion ocean acidification international program, going along with a global carbon program at the same time, working together. As a result of that, we developed the international Global Ocean Acidification Observing Network. So when you bring together scientists that are totally passionate about what they do, and they're willing to step out and provide leadership roles, and learn in real-time, by the way, and learn how to interact with their international partners. You learn you can do things that you never expected you could do by yourself. We were there with common interests and a common set of ideas. Our colleagues were as passionate as we were about it. We all became good friends. We worked together on many publications and documents for the government, and for the IPCC [Intergovernmental Panel on Climate Change], and for the United Nations. My colleague, Carol Turley, was the leading spokesperson for the United Nations work and invited us to go to a number of UN meetings and participate, so it just kept growing. Every day we get a call on, "Can you do this?" "Sure. We'll do it." "Will you join in on this? Absolutely. I'm there." By being positive, and telling your story, and being able to be responsive when you needed to, you got things done, and you got them done in a way that made a difference. You knew you were making a difference. I think part of the joy of the job is realizing that you had an opportunity to make a difference, and you did.

MG: I'm curious to hear a little bit more about the tools used in measuring the pH in the ocean and then what that showed you. I saw somewhere that the pH balance in the ocean has changed something like one hundred and fifty percent.

RF: That's what we anticipate might happen by the end of the century, 2100. What we saw in our work, and we have documented this globally now, is that we learned how to make very precise and accurate measurements of dissolved inorganic carbon and pH and total alkalinity. That allowed us to determine that anthropogenic signal. So that means that we could determine how much human- caused CO_2 is exchanging across the air-sea interface and changing the surface chemistry of oceans. It was my job to figure out how it was changing throughout the oceans, entire oceans. We could do that, and that's because we were making extremely precise measurements. Our DIC measurements, for example, measures one to two parts in twenty-five-hundred parts – very, very precise. Our alkalinity measurements were not quite so precise, but very good, two to three. We were measuring pH to a level of about 0.001 pH units. So just incredibly good capabilities. We had extraordinary people like Andrew Dickson and Bob Byrne, who were just teaching us how to make these extraordinary new methods for measuring pH quite well using spectrophotometry. It was always a lot of fun because you could take a series of samples from surface to bottom, and you could put them in vials, and you add this dye, which is what you measure with a spectrophotometer. The color of the dye would tell you basically what the pH was. So if you put them in vials and line them up on a table – and I have pictures of this I can show you – you can see from your naked eye the changes in pH. Very high pHs are very dark purple, and the very low pHs are weaker and weaker purple.

You can actually see those changes. You know that they're real because you see them with your naked eye, but the spectrophotometer is amazing at determining the very subtle changes. It's nice because we have these vials on the table, and you take a picture of it, you can show anybody, "These are the changes we're observing." Then, you go back to that same place ten years later, or you go to that same place and measure it every week or every month, as we do at the time series stations, and you can monitor these changes. Our approach was to pick a number of time series stations throughout the world, and monitor the CO_2 changes, initially by ships going out there. But now with moored observations, we can see those changes as they are occurring. We've been monitoring them at HOT [Hawaii Ocean Time-series], and BATS [Bermuda Atlantic Time-series Study], and other stations throughout the world. They're all showing the decrease in pH. Then we come back ten years later with the global surveys, and we can see the global changes that have taken place over that ten-year period. So we can see from everywhere we look the decreasing pH. From the preindustrial to the present, the surface ocean pH has decreased by about .11 pH units, which is an increase in a hydrogen ion concentration of about thirty percent. The predictions are that if we continue on out to the end of the century, the pH could change by another .3 pH units, which would be a hundred and fifty percent increase in hydrogen ion concentrations. Since we are seeing changes right now, that thirty percent increase in hydrogen ion concentration, you can anticipate what the changes might be out to at the end of the century. So the biologists have been doing similar experiments in the laboratory. Now we're making measurements of the biology in the field. Sure enough, we're seeing enormous biological impacts, particularly on organisms that make a calcium carbonate shell or skeleton, such as corals or lobsters or scallops, and all these things that we like to eat. Well, on the West Coast, for us, it's crabs. Of course, up in Alaska, it's crabs. On the East Coast, it's scallops and lobsters. But these are major industries in the United States, and we're seeing impacts on all those animals. We also find impacts on shellfish, such as oysters and mussels. In 2006 and 2007, the oyster industry presented a very scary situation. What they had is they had five or six hatcheries along the coast that produced oyster seed that they sell to the farmers. The farmers then spread out their seed, and then they make oysters, and they grow them on oyster farms throughout the region. That's a major industry along our coast. It really supports the economies of all our coastal towns. It's a very important part of our economy. Well, in 2006 and 2007, the oyster hatchery folks were put on alarm because they can no longer produce the oyster seed, and they didn't know why. They thought this was being caused by a bacterium called tubiashii. They said, "Well, what do we do?" So they shut down all their operations. They cleaned out all their tanks. They got all the tubiashii out there. They then put the water back in the tanks. They started introducing the oysters into the tanks, and they died again. They died very quickly, within two and a half days. They said, "Help. We don't know what to do. We just used up all of our resources to clean out the tanks. We don't know what to do." Well, in 2007, we had done this cruise along the coast, and what we found was that the oyster larvae were probably being impacted by the pH of the water. The pH along our coasts was really quite low; it was like 7.9. It's supposed to be about 8.1. For some reason, we were seeing lower pH and lower aragonite saturation than anywhere else that had been observed yet. We talked to them. They invited us to their annual meeting. We talked to them. We said, "Your problem probably is the pH of the water, rather than bacterium, and it's probably caused by anthropogenic CO_2 and upwelling because we have strong upwelling all along our coast." They said, "Well, how can you help us?" They said, "We're willing to go to our governor and get our governors involved. Just tell us what we can do." They spoke to our governor, Governor Christine Gregoire, Washington State, and the governor from Oregon. Our governor jumped on it right away and said, "Well, we can build a Blue Ribbon Panel. We'll get you guys together to work with the scientists. We will see what we can do to support this from the stateside." They developed the Blue Ribbon Panel, led by Bill Ruckelshaus, a very famous person because he was the first head of the EPA [Environmental Protection Agency].

That Blue Ribbon Panel helped identify that, indeed, it was the changes in pH, and the scientists actually began putting their pH sensors right in the hatcheries themselves. That was led by my dear friend Burke Hales from Oregon State University and George Waldbusser. Together, we began to study this problem, and the states provided some resources that they gave to the hatcheries. The hatcheries invited us scientists to put our instruments right in the hatcheries themselves, which we did. Sure enough, we were able to clearly show that what was happening is that when the water that was brought in in the morning came in contact with the oyster larvae, the oyster larvae died within two days. We said, "Well, if you increase the pH of that water by adding sodium carbonate, you can raise that pH to levels even higher than 8.1 and see what happens." They did that; they added the sodium carbonate. This is something that's very cheap and simple. Sure enough, the oyster larvae did wonderfully. We were able to save the hatcheries thirty-five-million dollars in that first year. All that was because our senators from Washington, Oregon, Maria Cantwell, worked with our governor to provide some money, some stimulus money from the federal government, to support those hatcheries. They then invited the scientists to come in, and we were able to prove that was the cause. This is a perfect example of how science, and the federal government, and state government can work with industry to save an industry. We indeed did that. This became known throughout the country that this Blue Ribbon Panel, and the activities of the scientists, and the interest in working together became well known and spread out throughout the country. So California joined us immediately. Then we began talking with the hatchery owners on the East Coast, and they found they were having similar problems. So that spread out. Because of the widespread impacts that we were seeing on the East

Coast and West Coast, we were able to develop the national Ocean Acidification Program in 2009.

MG: There was one other research cruise I wanted to hear about. I think the first major one was on the *Wecoma*. Was there also a cruise on the *Ron Brown* that also went up and down the West Coast?

RF: Yes. Our research that developed from that original discovery in 2007 allowed us to initiate the Ocean Acidification Program, which was funded federally by the Federal Ocean Acidification Research and Monitoring [FOARM] Act of 2011. That established the national Ocean Acidification Program office in NOAA, and then, we set about planning and developing research cruises along our coast, which we conducted on the *Ron Brown* and other ships. Sometimes we were on the Oregon State ship *Wecoma*, as well. Our last cruise was on the *Ron Brown*. It was conducted in 2016. In that cruise, we brought together the chemists and the biologists to work together on a variety of different species. It was really exciting for us because we were able to co-locate all those chemical and biological samples. We were bringing on young scientists, led by Nina Bednarsek, who was working on our laboratory. She was able to bring in lots of young graduate students from the University of Washington, Finland, and the Netherlands. They all had their own unique expertise. It was very exciting. It's a great opportunity to spend your time out at sea with people that are very excited. For some of them, it was their first time out at sea. They all collected their individual samples and their individual organisms and brought them back, took them to the laboratories, and we were able to make numerous new discoveries of the impacts of ocean acidification on many, many different species at that time. Every one of those persons that were onboard that ship ended up with a publication about their work. The last one just came out this last week, as a matter of fact. Nina led the work on the pteropods. Now, we know a great deal more about how pteropods are the indicator species for ocean acidification throughout the world because they are so sensitive. We call them the canary in the coal mine for marine ocean acidification. We've seen impacts of pteropods in Puget Sound, and in the Arctic, and along our coasts, from Mexico to Canada. So we really are beginning to develop a huge understanding of pteropods. Nina found out the same kind of impacts were occurring on Dungeness crab larvae for the first time; we did not know that until that cruise. We were then beginning to understand with biological indicators what the impacts were on the metabolic processes that were occurring with organisms. We're really getting into the level of detail that you'd like to have to understand mechanistically all the different effects and how the different impacts on and many, many different kinds of species, and really economically important species. You begin to see how the ecosystem is being changed and how it's changing in real-time. We can see those changes. Because we had the chemistry, you could say, "You know what? Here's the impact of the chemistry changes on those organisms because they had that chemistry to go along with it." It's been very exciting. We're about ready to go on our next cruise this summer, again on the *Ron Brown*. We're excited to see how many more new discoveries we can make.

MG: What are the COVID precautions that are going into the planning?

RF: Well, in actual fact, the impact of COVID has been incredibly difficult for all of us, and not just for my work, but for the entire community. Last year, we had to cancel a whole bunch of cruises, including our ocean acidification cruise. We canceled it last year. It was supposed to be last summer, and we hopefully will be able to get out this summer. We had to establish a number of different COVID protocols and put them in place. They're very stringent protocols that we must follow: before a cruise, you have to be at the site where the cruise will park for over a week, and you have to be tested prior to the cruise, and during that week, you have to be tested, so you know that when you get on the ship, you're free of COVID. Then you have to mask the whole time, so go through that process. There's an enormous set of protocols that have been put in place, and that means that the scientists have to dedicate two weeks of their life prior to the cruise. Then, you go on a four or five-week cruise, and then you have to worry about how to get you and your samples home safely. There's a lot of planning that goes into it now. A lot of effort goes into that, and we have spent easily a week per month planning this cruise for the past year. So a lot goes into it.

MG: What will be unique about this cruise? Are you looking at something specifically?

RF: Yes. What we are trying to do now is to understand how the community of organisms exists. What we're looking at is, for the first time, the changes in phytoplankton. We haven't looked at that before. Then, the zooplankton communities that eat the phytoplankton, and so looking at the distribution of zooplankton species. Now, we're starting for the first time to look at small fish, ichthyoplankton, and the fish, of course, eat the zooplankton. So we were trying to see how those changes transmit through the ecosystem and show what the overall impacts are from an ecosystem approach. This cruise is unique in that we see many different types of environments. Going all the way from Canada and Mexico, you're looking at a lot of different kinds of environments and then different groups of organisms along the coast. So you can see the overall impacts. The impacts are complicated because we not only have to look at the changes in acidification, but we also have looked at the changes in temperature. For the organisms, it's the combined impacts that matter to them. They are struggling against a warming ocean and an acidifying ocean. For many species, it's the combined effects of warming and acidification that makes a difference to them.

MG: I didn't want to skip over anything from the 2011 and 2013 cruises. In 2011, you were looking at sea butterflies and upwelling. Does anything stand out from that cruise?

RF: Yes. 2011 was the first time we started to think about how we bring biologists onboard the cruise. So a very famous biological oceanographer, Bill Peterson from the National Marine Fisheries Service, was the leading scientist on marine zooplankton, and he worked out of Oregon. We got together with him, and he sent out his crew on our cruise. These were delightful people, and I was really glad to go out there on the cruise and really see biology at work for the first time. This was my dream to combine the chemistry and biology. He sent one of his group, Jennifer Fisher, who now leads that effort for the National Marine Fisheries Service to this day. We got together, and she collected a number of samples of zooplankton. Her interests were in the crabs and other species. We separated out the pteropods, the sea butterflies, and saved them. Then, a year later, in 2012, we collected more samples together. We gave those samples to Nina Bednarsek, who was my postdoc at that time, and she separated out the pteropods and analyzed them. We published that work jointly in 2014. So every single cruise, we kept building the biological effort. We added more and more biologists to the effort, but our overall intention over time was to really get a better understanding of how the changes in the chemistry were affecting the biology. As we did so, we kept making new discoveries along the way.

MG: In 2013, you were on the *Fairweather* up and down the West Coast.

RF: Yes, the Fairweather cruise was probably one of the most difficult cruises I was ever on in my career. The Fairweather was a wonderful ship, wonderful captain, great crew; they were terrific people. But mid-cruise, this ship had a generator problem, and we had to go into Newport. The generator essentially died. We had to change ships, so my laboratory director at the time found another ship for us, and we went out on different ships. So that meant we took all the equipment, all the experimental work at that time – we were doing experimental work onboard ship – take it off that ship and put it on the other ship, the *Point Sur*. We did that successfully. We finished the experiments. We were actually for the first time putting pteropods into tanks, adding in acidified seawater, and studying their impacts. We were able to do that successfully. But it was one of the most difficult situations we had because we didn't know what was going to happen when we went into Newport. The ship was going to take a long time to be repaired. So we were able to change ships. We're very fortunate that we finished the cruise.

MG: What efforts are taking place on the East Coast? The cruises I've heard about so far are all up and down the West Coast.

RF: As part of the Ocean Acidification Program now, we have efforts that occur on the East Coast, the Gulf Coast, and in the Gulf of Alaska. AOML leads the East Coast effort and the Gulf of Mexico. Through the ocean acidification program, we have an effort that occurs along the East Coast, and that's led by Joe Salisbury and Wei-Jun Cai. We have an effort that's on the Gulf Coast led by Rik Wanninkhof and his group at AOML, and we have an effort in Alaska led by Jessica Cross, and our own effort on the West Coast. So each year, we do one of those four cruises, and our approach is to focus on one region every year and focus all the effort on that region. So, for example, this year, we will be working on the West Coast again. At the end of this year and the early part of next year, we'll be working in the Gulf Coast. The idea is that each group has a similar type of cruise with chemists and biologists working together along the coast. That's actually working quite well. We've been doing that now for almost a decade, a little more than a decade.

MG: Can you talk about how the Ocean Acidification Program has evolved over time? Are we missing anything from its history?

RF: Okay, let's go back. In the late part of the timeframe, around 2008 and 2009, we began an effort to convince Congress that we needed to do research on ocean acidification, that we need to have a national program on ocean acidification. Through our congressional efforts, working with Maria Cantwell, the Senator from Washington State, and other senators throughout the country, we were able to put an authorization bill through Congress called The Federal Ocean Acidification Research and Monitoring Act. It got approved in 2009. Part of that act set up an office within NOAA to coordinate all research within the federal government on ocean acidification. So that was a big issue. We established that office in 2011, and we developed an interagency working group on ocean acidification. We now have fourteen federal agencies working together on that that meet monthly. That group is led by Dr. Libby Jewett, who is the head of the NOAA Ocean Acidification Program. She and her staff lead the interagency working group, and they report directly to Congress on the development of the program, the reporting that goes into the program by all the different federal agencies that participate, and laying out the plans to Congress. At the same time, her office maintains the program and the funding for all of NOAA. That work started in 2011. To this date, it's built up its capacity and the funding over the years. So it's a very well- run, well-developed program office that does an enormous job, not only for NOAA but for the country and its interagency work.

MG: I wanted to ask you now about the urgency and importance of studying and understanding ocean acidification. One thing that helped me understand the urgency of the issue is when you talk about the prehistoric past and compare it to the present.

RF: That's a wonderful story. Perhaps the most fascinating aspect of ocean acidification is how rapidly mankind is changing the chemistry of the oceans. When you think that we have changed the carbon chemistry of the oceans over the past two-hundred-and-fifty years so that we can see very dramatic changes throughout the entire world oceans to the extent that is larger than anything we have seen in geological time for perhaps the last fifty-million years or so, that is an extraordinary rate of change. When you can go back in geological time, you can see how organisms responded to abrupt changes in the chemistry of the oceans through the geological record. Many of my colleagues have done just that. So now we have a very good record of the changing chemistry of oceans. You knew that by looking at the carbon isotope signature within cores and how those species changed when these abrupt changes took place. Now in nature, these abrupt changes usually take place because of volcanic eruptions that take place, or because of comets, or other impacts on Earth that have hit the Earth throughout time. You can then compare the changes before and after the event took place. When you do that, you can see well, if you look at all the great events that have occurred historically, most of them have been related to volcanic events that have taken place. Some of them have been because of comets. But those disruptions caused, in many cases, a great change in the ecosystem, and such that you can now check and see how long it took them to recover from those abrupt changes. So during the great extinctions, we can see that, first of all, even with the volcanic events, even when there were these abrupt changes, they took place over long periods of time, tens to thousands to millions of years, as opposed to the similar types of changes we're seeing now occurring over one to two-hundred years. So the rate of change is much, much faster now than it was in the past, with the exception of that comet event sixty-five million years ago. But then you can look and see how the ecosystem responded. For the most part, they responded by re- evolving, starting all over again, and re-evolving their ecosystems based on the new chemistry that took place. Once again, you see that it takes tens of millions of years for them to re-evolve those ecosystems. They do it in ways that are different than when they're in the past. Some organisms are able to get through the great extinction events and carry on, but most of them had to start all over again and re-evolve and re-evolve in different ways. So the lesson learned from that is that the ecosystems of the oceans are very sensitive to change. They can change rapidly.

In some cases, many species die out and go extinct, and some recur because they re-evolve, taking tens of millions of years to do so. So now if we think about what is happening now, is that we have a wake-up call by the changes in chemistry we've seen so far and pH changes of 0.11

pH unit change. But our predictions out to the end of the century are quite dire and about as dire as some of these extinction events. But the animals have had very little time to be able to respond and adapt to these changes. They've had to adapt to the existing changes, albeit small. They're having difficulty adapting right now. But if we continue on with the release of anthropogenic CO_2 from burning fossil fuels out to the end of the century, they will see the kinds of changes that we saw in the past during some of these geological events. This is why the scientists are so concerned. This is why we feel that it's something that needs to be addressed right now. Because we are seeing the first stages of those impacts and how they're impacting our ecosystems with the combined effect of the temperature and the acidification. We are able to use that historical information to project out what the implications are in the future. That's what we're doing.

MG: Why do you think public awareness for ocean acidification is behind global warming or climate change in general?

RF: I think, quite frankly, climate change has been with us, and public awareness of climate change dates back to the '60s and '70s. As I said, when I was in graduate school, we knew about climate change, and we knew it because we were reading the papers from [Svante] Arrhenius and others in 1896, who talked about climate change. We had the benefit of the historical information, and climate change was a public issue in the '60s and '70s; you can see it in the public record. Ocean acidification, on the other hand, was only brought to light since 2004. It was only brought to light because of the significant impacts that we've only begun to realize over the last two decades. It takes a while for people to understand that, but more importantly, it takes a stakeholder community, the industries, to raise the awareness. When you have an impact, an enormous impact on a fishery hatchery that has an impact on the shellfish industry, therein lies how you communicate the real concerns that we have at the public level. That's exactly what happened on the West Coast of the United States. So that's happened since 2006 and 2007. We've only had ten to fifteen years to address this. I think our response has actually been quite rapid and quite knowledgeable. I remember Bernie Sanders talking about ocean acidification in some of his speeches. This has been an issue that has reached the level of the highest levels of government.

MG: You were just talking about extinctions and animals that are being threatened with extinction. Are there any that have been lost to ocean acidification or are on their way?

RF: I can't say that. What we have found in our most recent work, though – it was just recently published – is that since the preindustrial era has taken place, we have seen species that have been impacted severely. Some of the most elegant work has been done by Emily Osborne and colleagues that have looked at foraminifera. Foraminifera are really important to geochemists because all our understanding of the time history of temperature throughout time and carbonate chemistry throughout time comes from studying forams. Forams are the species that live in the water column; they form a calcium carbonate calcite shell, and then they sink to the bottom, and they're stored in sediments. You can collect the forams, and then study their chemistry, and determine what the temperature of the water was or determine the carbonate chemistry and determine what the pH of the water is. When we do that, we find out that the shells of the forams have been thinning over the past hundred years or more. We have a very nice piece of research right off our coast of Santa Barbara by Emily Osbourne of AOML that just recently showed that in our region, and this has been shown throughout the world as well. So then you start looking at other species like pteropods and other species, and we see that the thinning process has occurred. So that means that the organisms that provide an enormous food source for small fish – the pteropods provide fat and food for salmon and other species of fish – are being impacted right now. The question is, “Okay, how does that impact permeate through the food chain?” There’s a lot of work being done right now to say, “Okay, how do those fat reserves that are building up in the pteropods and other species like krill – how does that permeate through the food chain?” That’s really an important issue. We’re just beginning to study that right now. Our concern is that if a lower trophic level species is impacted, and that’s the primary food source for fish species that we care about, then that becomes an economic concern. A lot of our research is going in that direction right now. I don’t have a clear answer for you. I just know that we are seeing impacts at these lower levels, and we think it’s really important to study how those changes take place over time.

MG: You’re quoted as saying, “We haven’t reached a major tipping point as of yet.” So what would it take to make sure we don’t reach a tipping point?

RF: What I was referring to when I addressed that tipping point, a tipping point is a point in which we go too far, and we can’t go back. There’s no way to go back. So, for example, if some key species were to disappear throughout the world, that would be a tipping point. That key species may have an impact on species at higher trophic levels. You have to also understand how that key species will affect the other species. Just as I was saying about the zooplankton, the zooplankton are the food for the fish. So some key indicator zooplankton species go away, then what happens to the fish? In our region, we’re very concerned about that because we’re very concerned about our fishing industry and our crab industry and understanding how food is transferred from phytoplankton to zooplankton fish is very important to us. Our understanding right now is that yes, we are seeing impacts, and some of the combined impacts of temperature and acidification are severe. We see some species temporarily go away, and they move out of the area, and then when that cooling takes place. If we have a heatwave or marine heatwave, and some species go away because of the heatwave or because of the acidification, right now, we have cooling events take place, and they come back. We haven’t reached a tipping point yet because they come back, and they can be seeded by organisms from other regions where the waters are cooler or less corrosive. But it is an indication that these processes are occurring. It’s an indication that we should be concerned because if we’re having more heatwaves due to climate change and we have more acidification, perhaps the extent of the impact will be larger and larger. At what point can the organisms not be able to come back? At what point do the fish not come back? At what point does the fish stock get so low that we have to depend on other sources of protein for food? So these are the issues that we’re addressing right now. Certainly, we’re not past any tipping points that we know of quite yet, but the indicators are there.

MG: Wasn’t it believed for a long time that what was causing acidification was runoff or fertilizer?

RF: Well, let me explain it this way. One of the earliest signs that acidification was an important impact was in the open ocean. From our work from the GO- SHIP cruises and from the work at the time series stations, like HOT and BATS, we were able to document the acidification over time and clearly document. In the open ocean, it's the dominant change over long-term change in pH. It's pretty much the only mechanism for the long-term changes that occur. But when you get into the coastal environment, there are other sources of change that can also impact pH in major ways. Those sources can even overwhelm the acidification signal. In some places, it does. Consequently, you have to be able to determine the ocean acidification from CO_2, compared to the ocean acidification from changes in nutrient inputs, from changes in other sources of acid gases, like sulfuric gases and nitrogen gases. We need to look at those gases as well. You also need to see if the changes in nutrients affect the biology and, therefore the biology affects the chemistry. In some places, that's exactly what's happening. When you track changes in pH and coastal waters, you have to be cognizant that those changes are not only due to the acidification from CO_2 but also due to these other sources, and we've been able to do that. We've been able to document that. That's part of the overall discussion. Some areas are still dominated by local nutrient inputs, particularly some of the rivers on the East Coast and some local areas, like in Puget Sound and other areas. The changes in nutrients play a role, and the changes in nutrients affect the phytoplankton and zooplankton. Those biological changes change the pH. So you got to identify those changes. We're able to do that.

We're able to determine which sources are where, but it takes a lot of effort, a lot of research. But, over the longer term, the release of anthropogenic CO_2 into the atmosphere and its impacts on ocean chemistry, if we continue down this path of using fossil fuels for energy, will be the dominant and most impactful change in pH. That's clearly shown in all the models. We understand that quite well.

MG: You mentioned earlier the Federal Ocean Acidification Research and Monitoring Act. Did you testify in front of Congress in support of that bill?

RF: Yes. The history was that myself and Vicky Fabry, who was on the cruises with me, testified before Congress just on acidification impacts alone. We did that a couple of times, in the House and in the Senate. Then, in 2008, we were asked again to come back before Congress to testify about the Federal Ocean Acidification Research and Monitoring Act. There were a couple of hearings. The House hearing was probably the most significant hearing at the time. That House hearing was specifically about the act itself. Myself, Joanie Kleypas, Scott Doney and Brad Warren and others testified. We were testifying primarily about the importance of doing research and funding research on acidification and impacts on the stakeholders and impacts on the industry. But also, the testimony was about how we would put together such a program within the federal government and how that might work. That was extremely well-received. Shortly after that testimony, the text of the FOARM Act was put together, both again in the House and the Senate. So there was a lot of joint House-Senate activity to do that. It was later signed by President Barack Obama in 2009.

MG: When did you get the nickname "Grandfather of Ocean Acidification?"

RF: Let's see. It stemmed from one of the meetings that we had shortly after the Blue Ribbon Panel report was released. I was doing interviews on the Blue Ribbon Panel itself. One of the reporters from the *Seattle Times* nicknamed me "the Grandfather of Ocean Acidification" during that interview. It was a little premature because I didn't have any grandchildren yet. But now I have grandchildren, so I'm very happy to take on that name. I have a really wonderful grandson, Charlie, a delightful grandson who spends a lot of time with us. So I'm very happy to take on that name now. I wasn't quite so sure what to think about it at the time. But it took shape. A lot of people liked that idea and had that perception, at least locally here in Washington, Oregon, and California. I'm not sure it's worldwide by any means.

MG: Were you involved in Paul Allen's Ocean Acidification Challenge. That was something I read about in my research.

RF: Yes, as a matter of fact, I was. Paul Allen and his group [Paul G. Allen Family Foundation] got very interested in ocean acidification. They put out a challenge to create a lot of excitement and interest in ocean acidification and conduct research on ocean acidification. Their goal was to highlight the importance of this by funding research in areas where it would make a difference and make a difference in very clever ways. They put out a challenge, a request for proposals. That was met with many beautiful proposals being submitted, and two were selected. One was selected out of the University of Hawaii to see whether or not we could help coral reefs respond to ocean acidification by understanding how they could change or evolve in a high acidification world and help them see how that process might occur. The second one was led by Betsy Peabody and Joth Davis, and that one was accepted. The idea there was to develop a capability to have a kelp farm start from scratch and to monitor that kelp farm in real-time and see if it can take up carbon, and remove that carbon, and change the chemistry of seawater, and change it in a way that would be positively impactful to the marine ecosystem around it. Then, to harvest that kelp and find ways to utilize that kelp that could be economically important. So we did that. We participated in that. My group did the chemistry part of it. We developed a kelp farm in the Northern Hood Canal and monitored it for two years, and we not only studied the kelp itself and the growth of the kelp but studied many ecosystem species within that kelp farm. We both monitored the chemistry and modeled the chemistry. A beautiful modeling effort was done. We came out with some very important and significant results. We harvested all the kelp. We put it on an experimental farm conducted by the University of Washington and showed very clearly that if you use kelp as fertilizer, it can greatly enhance production. So that was a very significant result. We also worked with several chefs because this particular species of kelp we were working with is highly edible and can be used in salads. Therefore, it can be used in a very beneficial way as food. You can use it for food for people, but you also can use it as food for farm animals. That turned out to be a promising approach. So this is one of the very first early experiments that took place, and it was really quite successful.

MG: Can you talk about how you see the future unfolding for NOAA's Ocean Acidification Program?

RF: Could I extend it a little bit further?

MG: Sure.

RF: I'd like to say what my perspective on the future is for everything related to the CO_2 problem. I think we're at a very exciting time in our history right now because I think the emphasis on the significance and importance of understanding our global climate and understanding mankind's impact on the global climate is very well understood by society and how important it is. With the impacts of the most recent hurricanes and the most recent fires, we're really beginning to make the connection quite well that our climate is being changed by fossil CO_2 burning and by the release of CO_2 in the atmosphere. It has an enormous impact on the changing temperature, the changing amount of water in the oceans, and the overall impacts on storms, floods, hurricanes, and forest fires. Such that I think that we're really understanding the issues very clearly right now. Then when you add in the impact of acidification, which is caused by CO_2 as well, and we see that we're also having an impact on our marine ecosystems and our fisheries, and the impacts are due to changing temperatures and the changing CO_2 levels, I really began to think that now is the time to address many of these scientific issues in a way that can be expanded and can perhaps be expanded in ways that we need to implement. We need to do everything we can to reduce CO_2 emissions as much as we possibly can. I think our country and many other countries throughout the world are beginning to address that by responding to the Paris Accords. I think that we also realize that we need to support research on the impacts of these changing environments at the local and regional levels so that we can respond at the local and regional levels, as the states are doing now, as our local communities are doing now. I think this is really positive. I'm really excited about that. The knowledge that we have, the capability to provide energy for our people and provide food for people in a way that is sustainable for the environment, is just recently being appreciated. We not only have a direction to go and a mandate to go there, we also have a mandate to go in a way that will sustain our environment in a meaningful way. That's a huge change that has taken place over the last decades. It's something that we need to take advantage of. We need to take advantage of that right now. All the scientists are saying that we really need to get started right now. One new area where we need to think about is developing technologies that reduce CO_2 emissions that can be impactful in terms of the global carbon cycle and also be good for the environment. These are called net emissions technologies, and there are many, many kinds of carbon removal technologies right now. A lot of thought is being given to develop these technologies and see how we can develop them in a way that will help us to sustain the environment in a very positive and effective way. The approach of continuing to do the research on the impacts of climate change and acidification on the environment has to be increased and accelerated. The approach to monitor those changes has to be increased. But the approach to actively reduce the emissions and determine what's the most safe and effective way to do that has to be developed now. It's exciting to me at this time to see many government agencies and foundations willing to come together to do just that. The recent National Academy of Sciences meetings that are taking place now and the reports that have come out and will come out are very exciting because I think they will set the direction for the research in the future that we really need to consider carefully.

MG: I want to ask you about your family life and life outside of NOAA. But is there anything I'm missing so far in terms of your career?

RF: I would like to give a final statement about my career, and I would like to talk about my family.

MG: That's fine.

RF: Which way do you want to go?

MG: Tell me your final statement about your career with NOAA. We can close the career chapter, and then you can tell me about your life outside of work.

RF: All right. My career at NOAA has been probably one of the most interesting and exciting times for me because I was able to join NOAA at a time when it's very close to the beginning. I started in 1974. I started at a time they were just building the Pacific Marine Environmental Laboratory, and I was able to grow all the programs along with NOAA. I was really privileged, and privileged is the right word, to be able to participate in developing many of these programs that exist to this day. I am very humbled by the fact that I realized that during the course of that time, people put a lot of faith in me. I was able to work with the leadership within NOAA on a one-on-one basis, a personal basis. Throughout my career, I was able to get to know all the leaders quite well. These were enormously amazing individuals who were very impactful in our lives. They, during that time, spent their time with the young scientists like myself, talking with us about science, talking with us about the future of NOAA. I really was able to grow as NOAA grew. My goal through that whole time period was to link NOAA science up with the science that was occurring in our ocean community. I felt very strongly about that. I wanted to see NOAA work together with the National Science Foundation, with the USGS [United States Geological Survey], with the Department of Energy, and the EPA. I wanted to do it in a way that we would all work collaboratively. So I was really fortunate enough to get opportunities to do that with the NOAA Vents Program, starting out, and then helping to develop the NOAA Carbon Program and the US carbon program, and participating on both sides. It was really gratifying to participate in the committees on both sides. I really appreciated that. Each step of the way, we had opportunities to expand the vision of NOAA, to expand the vision of how agencies could work together and expand the vision of what that meant for our community. For me, it was probably one of the most exciting parts of my career. We were expanding the ships at the time, we were expanding the capabilities at that time, but we were doing it by working on programs that meant a lot to society and to our environment, and to NOAA's overall role and mission of being great stewards of the oceans. I believed in that, but it was really a great experience to work with the leadership in NOAA, and the leadership in OAR [Oceanic and Atmospheric Research], and our agency, working with outstanding leaders, Rick Spinrad and Craig McLean, and all the leaders at OAR have been just tremendous. I had a great professional life, working together with these folks one-on-one, and seeing the vision together, and being able to have a role to play in that. For me, this has been very exciting, working with my laboratory directors through the years, Eddie Bernard, Chris Sabine, and Michelle McClure; all these folks had the same vision. We had the opportunity to work together and make that vision happen. My vision for NOAA in the future is that this is an exciting time, and we will be able to go from there into even more exciting research and more impactful research because we now have the tools in place to do the job that the US people want us to do. NOAA is a leader now in climate science. It's a leader now in marine ecosystems. It's really an exciting time to be a researcher. I think we can all appreciate the job that NOAA has done, pulling all the pieces together, bringing all the line organizations together, and working together towards a common good. I have just been very happy to be a part of that.

MG: Well, tell me about your life outside of NOAA. You talked last time a little bit about your wife. I was curious to hear a little bit more about her and your family.

RF: Well, I have to say that the journey for my family has been very strongly linked to my job. This is because I have a partner in life, my wife Terry, who had transcended from before the job existed. We met when I was in graduate school, and we got married in the middle of graduate school. We spent the last part of graduate school together, and then we both wanted to move to Seattle. So this job in NOAA was very exciting to us. But that meant we had to start our family and develop our family without having much in the way of support from home. We had to do it ourselves. So we moved there. We developed new friendships, but we depended on each other all the way through. We made all our decisions [together]. My wife was a supervisor at the child and youth clinic for King County. For all of her career, she had a really responsible job. We raised three wonderful children, and they had to put up with me going to sea for months at a time. She had to figure out how to take care of these three young children when I was out to sea, sometimes for two or three months, and still take care of her job and still take care of our three children. She just did a marvelous job. Even when I was out to sea, we were talking almost every day when we could. Sometimes we couldn't because communications early on were not that good. But we made all of our decisions together. Because of that, I think we have a very tight-knit family. We all enjoy each other very much. My daughter is now a very well-known scientist in her own right at the University of Iowa in Iowa City. She's in genetic counseling, and she counsels patients on genetic diseases. A lot of my discussions with her have to do about genetics and how that influences biological systems. So I have a lot of wonderful discussions with her. She's a very brilliant speaker and accomplished scientist in her own right, and so I'm very, very proud of her and the kind of scientist she's become. My two sons are in business, and they're doing extremely well. But as a family, we did everything together. We went on all the trips together. When I went on cruises, we went to the cruise sites together, so they could see the ship, and see the submarines, and see what dad did. I asked all these wonderful questions. I would go into their classrooms and teach in their classrooms. I would teach about what we were doing at the deep-sea vents, and I would teach about what we were doing with the ocean acidification. I would do that all the way through grade school and high school, and I would coach their sports. I had a great love for sports, and so I would coach them in basketball. We would be running around. I'd come home from work, pick up the kids, go to basketball practice, or go to whatever event that they had and try and be a participant in their activities as much as I possibly could. Later on in life, now I'm doing the same thing with my grandson. We just love it.

MG: That's wonderful.

RF: I don't know if I said this to you, but my whole family has a strong sports background. My father was a college basketball coach and athletic director at the school that I went to. I was the worst athlete in my family, and they always kidded me about that, but I still was a pretty good athlete in my own right. I played football, basketball, and baseball in high school. But the love of sports has made a huge difference in my life, and the love of competition in a positive, impactful way, and how working together in sports teaches you how to work together in life. So I've used that background in my job. I use that background in my thinking in how we can get people to work as teams and do teamwork together in NOAA. Everybody knows their job well. Teamwork is everything in sports, and that's the way I approached my work in NOAA.

MG: Well, I've gotten to the end of my questions and just in time, but if there's anything we're missing, we can always schedule another call or add it to the transcript.

RF: That sounds great. Yes, I've lost my voice now. So I think this is a good time to end. I look forward to working with you. Can you just give me some sense of the timing on that part of it?

MG: Sure. I will turn this off, and we can talk some more. Let me just first thank you for the time you spent with me today and last time. This has really been such a treat, and your story is so impressive.

RF: You have a wonderful way of bringing people out of their normal realm and making it very enjoyable and fun. I can see why Eddie Bernard had so much fun with you now. I was very impressed with his interview, and I look forward to seeing it.

---END OF INTERVIEW---

Reviewed by Molly Graham 2/11/2021
Reviewed by Richard Feely 3/9/2022
Reviewed by Molly Graham 3/11/2022