REMARKS BY THE HONORABLE JOHN KNAUSS, UNDER SECRETARY OF COMMERCE FOR OCEANS AND ATMOSPHERE

It is indeed a pleasure to come back to Scripps; I always enjoy returning. It's a particular pleasure to be invited here to celebrate an extraordinary event—CalCOFI's fortieth birthday—forty years of almost continuous, systematic observations of the ocean. These are not simple observations of tides or sea-surface temperature at a few spots along the coast, but a complex set of physical, chemical, and biological observations at many locations off the Pacific shore that require the skill, the care, and the dedication of many. There's nothing else like this program on this scale in the United States, and with the possible exception of the North Sea, I'm not aware of anything like it anywhere else in the world.

We are also here to celebrate forty years of cooperative work between the state and federal governments and a major public university. I might note in passing that I believe this alone makes CalCOFI a remarkable and unusual program, particularly the fact that the University of California is still involved.

Universities have many wonderful attributes, but the care and feeding of long data sets is not one of them. Universities tend to go where the action is. Long-term, systematic monitoring programs generally have a life span that corresponds to that of a professor. A professor retires, and suddenly the set of observations that he or she so carefully nurtured ceases to be a high priority of the department. Too often the collection ends, or its quality is allowed to erode.

I watched that almost happen here at Scripps, when I was a young graduate student and Professor McEwen retired. The question arose as to whether Scripps would maintain his collection of surface temperatures and tide gage records taken from the end of the pier. There was a time when even that simple set of observations was in danger of being abandoned because no member of the faculty was prepared to take responsibility.

But CalCOFI has outlasted its original participants, although a few like Joe Reid and Roger Revelle continue to be actively involved in oceanography. I'm told that none of those involved in the early years of CalCOFI are still part of the program.

Even I can claim some indirect part of the action during that first year of CalCOFI. One of my first tasks as a new employee in the Office of Naval Research in late 1949 was to answer a request from Revelle to find navy loran sets that could be used on the research vessels involved in the program (at no cost to Scripps, of course). It turned out not to be all that difficult to fill Roger's request, in return for which he bought me dinner at the Cosmos Club on his next trip to Washington.

As Roger indicated, CalCOFI was probably the original idea of Harald Sverdrup. CalCOFI was conceived in the grand tradition of ICES—the International Council for the Exploration of the Sea, a multinational effort designed to explore the relationship between fisheries and the ocean environment in the North Sea.

I had an opportunity, while on sabbatical two years ago, to spend some time as an amateur historian of marine policy and to look at how British fishery policy developed during its period of explosive growth more than a century ago. In the process I learned a bit about the early days of ICES, which, by the way, is celebrating its eighty-fifth birthday this year.

Although Great Britain had by far the biggest fisheries of the North Sea, ICES was essentially a Scandinavian idea. It was developed from the ideas of such scientists as Otto Petterson and Johan Hjort. Their goal was to explain the fluctuations of such resources as the herring fishery, the cod fishery, and the great bottom fisheries, mostly plaice, by studying the life histories of the fish, their environmental requirements, and relating those requirements to the ever-changing physical and chemical environment of the North Sea. And that was and is, of course, the goal of CalCOFI. Only in CalCOFI, the fish was originally the sardine, and the environment was the California Current.

ICES was a great success from the beginning, but—and this is part of my story—not in its original mission. In retrospect, its greatest success in its first few years was in establishing the standards of physical oceanography. Through its short-lived International Hydrographic Bureau in Oslo, under the leadership of Fridtjof Nansen—that remarkable explorer, scientist, and statesman—it laid the groundwork for modern physical oceanography. It was there that Knudsen invented "standard seawater," making it possible for technicians to measure salinity to five significant places in the cramped laboratories of small research vessels. It improved on the development of deep-sea reversing thermometers, so they could be trusted to give accurate readings of *in situ* temperature to a few hundredths of a degree. It was through the bureau that Ekman developed his equation of state of seawater, so if one knew the temperature, salinity, and the depth at which the water was taken, one could measure density to a few parts in a million. This in turn made it possible to calculate geostrophic currents. And of course there was the Nansen bottle, which allowed not only the capture of uncontaminated water at depth, but also the ability to string a dozen or more such bottles on a wire and thus collect many samples simultaneously.

All of this was developed by ICES in its first few years, mostly before 1910, and these were the techniques of CalCOFI when it began operation after World War II; these were the techniques of physical oceanography up until about twenty or twenty-five years ago. However, ICES had less success in its original goals, particularly in relating the physical environment to the abundance and distribution of fisheries.

ICES was originally conceived as a five-year experiment. It is still going on. In 1909, at the end of its first five years, when the original budget was up for renewal, and many, including the fishing industry, were questioning its success, Johan Hjort wrote: "We hope, consequently, that the results now obtained will facilitate to a substantial extent further investigation in this difficult but yet so important a field of inquiry."

Although written eighty years ago, this has a familiar ring to those of us, and I expect there are a few in this room, who at one time or another have had a large experiment not quite live up to our hopes and have had to go hat-in-hand to the National Science Foundation or to the director and admit that we might have been overly optimistic in our original proposal. ("But we are getting close, and you don't want to cut off our funding now, do you?")

But the problem of relating fisheries to hydrography was and continues to be an extraordinarily difficult one. Listen to one of the best fishery biologists of the last generation, Michael Graham, in his excellent book *Sea Fisheries*, almost fifty years after Hjort's statement: "Future editions of this book would certainly include more on the relations between fisheries and hydrographic conditions, but at the present time they are imperfectly understood." That was in 1956. So it was when CalCOFI started some forty years ago, and so it was and has been for much of its existence.

These relationships are slowly yielding to analysis. For example, one now can do a reasonable job of predicting next year's anchovy population from this year's temperature at the time of spawning. But, and I expect that those of you who are professionals in this room know it, understanding the detailed relationship of fisheries and hydrography continues to be a challenge.

I would like to celebrate another aspect of CalCOFI. Just as laying the foundation of modern physical oceanography was one of the unanticipated achievements of ICES, so is the magnificent, unparalleled forty-year time series of biological, chemical, and physical observations of the oceanographic conditions off the California coast a major achievement of this program. It has produced a data set that finds an increasing number of uses not related to its original purpose.

There are two parts to this success story, and they are not unrelated. The first is the quality of the data. It is not easy to maintain a tradition of quality control in a complex observational program that grinds on month after month, year after year, with an ever-changing cast of technical observers. But it is a tradition that is absolutely essential in a program such as this. It is the tradition embodied in that wonderful Teutonic taskmaster, the late Hans Klein, who oversaw the data collection and processing program of CalCOFI for so many years. He accepted nothing less than the most precise, most careful observations and the most rigorous analyses.

If I may be forgiven a personal note, it was a tradition and a program that I inherited when I began my work on the equatorial waters, and one I had reason to recall a few years ago when I retired as dean at the University of Rhode Island and began clearing out some old files. Among the artifacts, I found an old CalCOFI form 4.5, one of those marvelously complex plotting sheets designed by Hans that allowed one to plot not only the traditional temperature-salinity relationship, but a number of others as well, such as silicate versus thermosteric anomaly, and temperature versus oxygen, and all on at least two scales.

Time, as it does for events of one's youth, has a way of eliminating the rough edges. I can only dimly recall working over a light table on the equator, in the days before either air conditioning or CTDs, sweat dripping over those damn forms (Hans had them printed on high-quality paper so that they would not disintegrate when sweated upon), trying to manipulate a French curve between observational points. I can still remember the Hans Klein instructions to lay the form 4.5 from the preceding as well as the succeeding stations underneath the one being worked on and use the observational points from those stations as a guide for interpolating. This was an early form of what we now call objective analysis, but the computer does the work for us these days. I hope that somewhere on this campus a few form 4.5's still exist, along with the detailed Klein instructions, including, as I recall, a shift in the hardness of the pencil depending on the quantity being plotted.

In addition to all that physical and chemical data carefully observed and recorded, there is the wonderful biological collection of CalCOFI—the fish eggs and larvae, phytoplankton, zooplankton, and the fish, all carefully collected, carefully preserved, and carefully archived.

At a time of increasing concern about global change, at a time when the prospects are increasing that we will soon be able to predict yearly and decadal changes in our atmospheric and oceanic climate, and at a time when we are looking for biological and chemical trends over time, many are scrambling to find long-term data sets upon which to test ideas, to look for small signals hidden in a large noise level of what must still be treated as random variability. The CalCOFI data set is almost unique. Certainly there is little like it for the Pacific, where our ideas about atmospheric ocean coupling are more advanced. And there are few, if any, long sets of biological samples where one can test trends in pesticides, for example—ideas not dreamed of when CalCOFI began, using techniques not invented at the time CalCOFI began. Like Fridtjof Nansen's International Hydrographic Bureau, which in retrospect was one of ICES's greatest contributions to science during its first decade, so the magnificent records of observations of the California Current may be one of CalCOFI's greatest contributions to future science during its first forty years.

The care that Hans Klein and those who succeeded him have given to the collection and analysis of data ensures their quality, something that one cannot always guarantee with some other long-term data sets when attempting to use them for attacking problems not originally contemplated in the experimental design. CalCOFI is a wonderful program; it has a unique set of records, which can only become more valuable as they are extended in time. The data and the samples are to be trusted, and they can be used with confidence.

This afternoon there will be a seminar dealing with certain aspects of global change. We've all known for some time that the key to the interannual and decadal changes in our weather is the oceans. We've known that in an abstract sense, and more recently we think we are beginning to understand the relationships. Certainly the success that we are now having in relating the so-called Southern Oscillation to El Niño events on the west coasts of both North and South America gives us hope that this complex interaction can be unraveled further.

We also are beginning to understand the role of the oceans in global warming, triggered by the increase in such greenhouse gases as atmospheric carbon dioxide. One can perhaps best see the ocean role by examining two relatively recent models of how and how much the earth warms as the greenhouse gases increase. One model, out of the United Kingdom, treats the ocean more or less as a boundary condition. It shows the temperature of the earth warming up less in the tropics, but increasingly as one moves poleward. The heating is more or less symmetrical about the equator. The second model uses a three-dimensional ocean and is generated by Suko Manabe and colleagues at NOAA's Geophysical Fluid Dynamics Laboratory in Princeton. Like the U.K. model, it indicates limited heating in the tropics, and increased heating with latitude. But unlike the U.K. model, it indicates that almost all the heating is in the Northern Hemisphere; the Antarctic Circumpolar Current absorbs the heat from the Southern Hemisphere, with the result that there is almost no atmospheric heating at high latitudes in the south.

I'm not certain that anyone, including the modelers, believes their predictions in any great detail, but they do point to the importance of our understanding the circulation of the ocean and its heat budget much better than we presently do.

We can certainly learn something about the grand circulation patterns of the ocean from satellite observations. From the pattern recognition that one can observe by looking at the surface temperatures of the ocean, and from satellite altimeters, one can measure the shape of the sea surface and in turn derive the equivalent of surface pressure maps of the ocean. But we cannot "sound" the ocean from satellites as we can the atmosphere. We will need *in situ* measurements of one kind or another if we are truly to understand the circulation and the heat budget. The CalCOFI data set provides us with forty years of monitoring one small but essential piece of the ocean circulation. I expect that studying that data set will play an important role as we design our total ocean monitoring system. Whether that system follows the CalCOFI form is not so important, but I expect that the interannual and decadal variations one can find in the California Current as indicated by the CalCOFI data can be used as a guide.

California, this nation, and the world are fortunate that those who began this program have continued it. Having been party to a number of joint efforts, I can only assume that the cooperative arrangements between this university, the state, and the federal government have not always been easy. That you have succeeded as you have is a tribute to the patience, the tolerance, and the statesmanship of many.

Congratulations, and happy birthday.