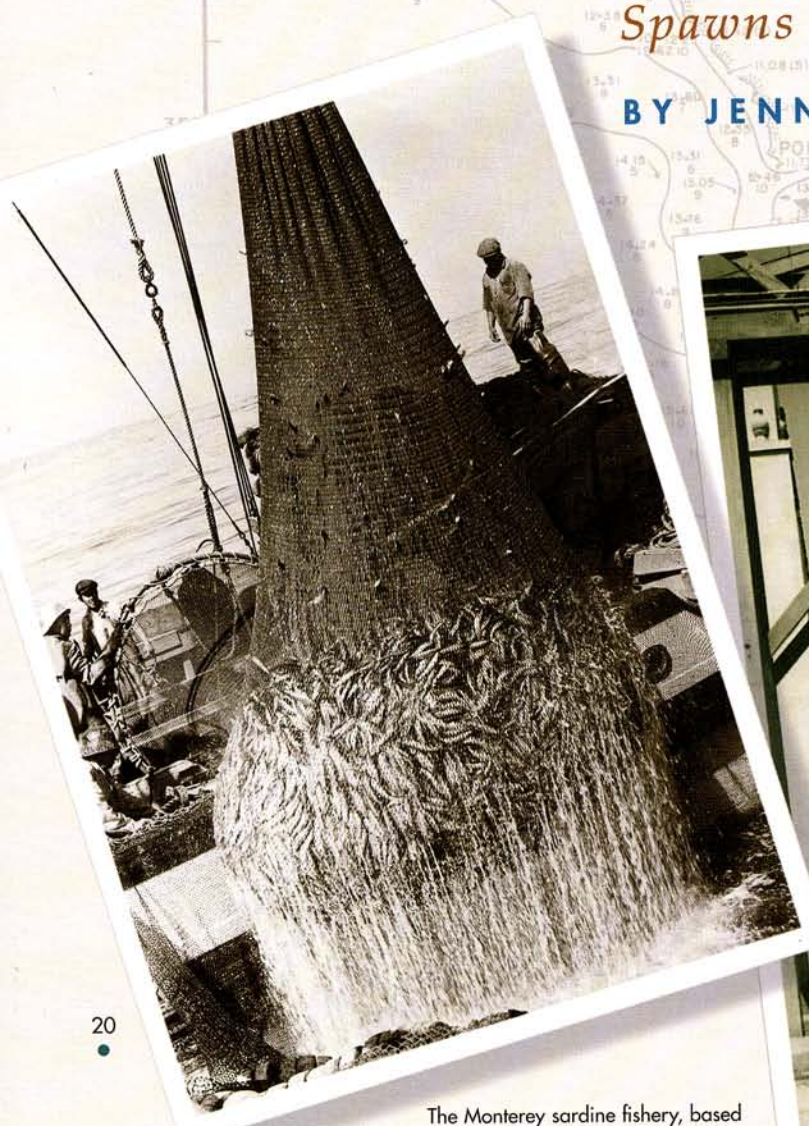
Surveying Changes IN THE SEA

50th CalCOFI Year

50-Year Program Spawns Bounty of Data

BY JENNIFER E. CHUNG



The Monterey sardine fishery, based along Cannery Row, was a booming industry in the 1920s and 1930s.

IN 1952, WHILE CASTING ABOUT for graduate study programs, a young John McGowan wrote a letter to Scripps instructor Martin Johnson, an invertebrate zoologist studying plankton. Johnson encouraged McGowan to apply to Scripps, apprising him of a new program, called CalCOFI, that involved repeated measurements of the California Current. McGowan, now a professor emeritus of biological

CalCOFI technicians use extra care deploying a CTD rosette in the wintertime waters of the California Current.

oceanography with Scripps's Marine Life Research Group (MLRG), looks back on those days and says matter-of-factly, "The reason I came to Scripps was CalCOFI."

The California Cooperative Oceanic Fisheries Investigations, known as CalCOFI, has had an enormous impact on the research of many at Scripps, and beyond. In addition to providing a foundation of data for researchers to build on, the program has assembled the largest zooplankton collection in the world, revolutionized fisheries management, and helped scientists understand large-scale environmental change. Celebrating its 50th year of continuous operation in 1999, CalCOFI boasts a history encompassing hundreds of thousands of ocean measurements and net tows taken during 300 cruises. This is precisely what makes the program so significant: history.

CalCOFI Time Line

550,000 metric tons of sardines caught off California coast, more than any other fish catch in North America. There are 24 canneries along Monterey's Ocean View Avenue, later renamed Cannery Row.

A collaboration established to investigate the sardine fishery's collapse; participants include Scripps, the California Academy of Science, the Stanford Hopkins Marine Station at Monterey, the NOAA/NMFS Southwest Fisheries Science Center, and the California Department of Fish and Game.

1945 1946 1947 1948 1949 1950 1951 1952 1953 1954

Sardine fishery falls to 100,000 metric tons. Fishing industry imposes tax on catch to support research on causes of population failure.

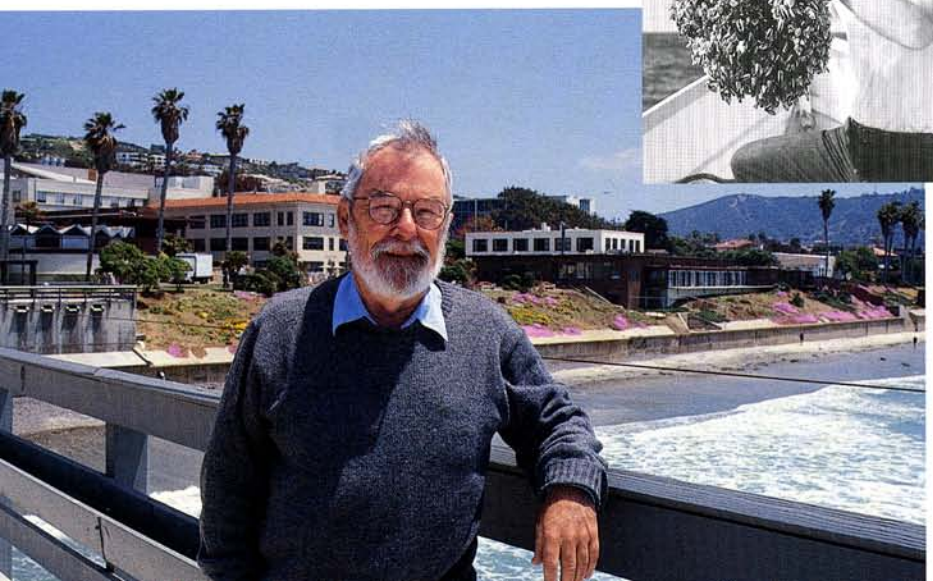
The collaboration officially named the California Cooperative Oceanic Fisheries Investigations (CalCOFI).

EXPLORATIONS
SUMMER 1999

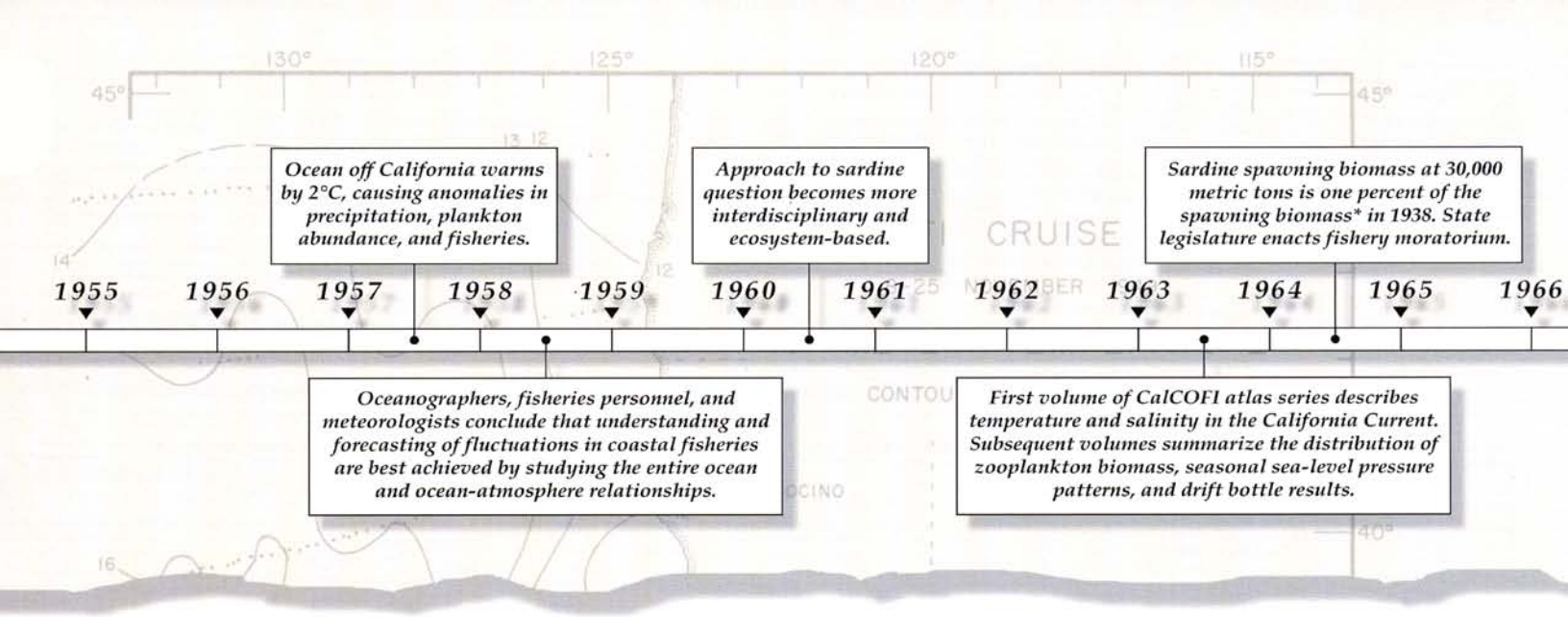
The CalCOFI story begins with the mystery surrounding the disappearance of a small silvery fish, the sardine. During the 1920s and 1930s more sardines were caught off the California coast than any other fish in North America. Then the annual catch plummeted from 550,000 metric tons (606,265 short tons) in 1945 to just 100,000 metric tons (110,230 short tons) two years later, and California's economy suffered. CalCOFI was formed in 1949 to determine the cause of the sardine's radical decline. It is now a collaborative effort among MLRG at Scripps, the California Department of Fish and Game, and the Southwest Fisheries Science Center (SWFSC), a regional branch of the National Marine Fisheries Service.

CalCOFI detectives began the search for clues in the California Current, part of a great clockwise circulation of the North Pacific Ocean that transports water along the California coast. Early on they surveyed 670,000 square miles (1,735,290 km^2) of ocean during monthly cruises. A total of 122 hydrographic stations extended from the mouth of the Columbia River in Oregon to the tip of Baja California, stretching 400 miles (644 km) outward from the coast.

CalCOFI researchers began to collect samples of larval fish and plankton in net tows, often using equipment designed by Scripps scientists. To understand how the organisms interact with the environ-



Graduate student John McGowan (center), during the 1953 Transpac Expedition, displays a fishnet float encrusted with barnacles. Now a Scripps professor emeritus, McGowan (left) remains active on campus. Tom Hayward (right), research oceanographer and academic administrator with CalCOFI, at sea during a recent CalCOFI cruise.



Amy Hayes, a fishery biologist with the SWFSC, and volunteer T. J. McCann prepare a bongo net for deployment. Created by McGowan and fellow Scripps researcher Daniel M. Brown in 1966, the net has become a standard device for zooplankton sampling.

ment, the scientists initially measured ocean circulation, temperature, oxygen, and salinity. Through the years they continued to add data, such as on nutrients, chlorophyll, and pelagic birds, to the time series.

Samples of fish, fish eggs and larvae, and plankton obtained during CalCOFI cruises become part of Scripps or SWFSC collections. More than half of the zooplankton samples in the Scripps Planktonic Invertebrates Collection originated from CalCOFI cruises. The collection provides historical patterns for various species and environmental conditions and is available for anyone conducting zooplankton research.

For instance, the collection has been used to conduct content studies on the pesticide DDT, banned in most industrialized countries in the early 1970s. Researchers at SWFSC were able to trace the buildup of DDT in the marine environment and the subsequent reduction of the hazardous chemical after it was banned.

Sixteen research projects are currently supported by the collection. Half of these are Scripps projects. According to the collection curator, MLRG professor Mark Ohman, the Scripps plankton collection is the largest in the world, housing about one billion specimens representing thousands of species. Each year it is expanded with more specimens from CalCOFI.

"The original purpose of the program was to look at the distribution and abundance of sardine eggs and larvae. Gradually that became the distribution of all larval fish, and much more," says McGowan, explaining how CalCOFI's scope has broadened over the last half century. But, from the beginning of the program, researchers knew that the sardine could not be studied in isolation from its physical, chemical, and biological environments.

In 1958 CalCOFI scientists held a symposium on "The Changing Pacific Ocean in 1957 and 1958," attended

By counting fish scales taken from sediment cores off Santa Barbara, CalCOFI scientists are able to reconstruct an 1,800 year record that shows sardines follow a cycle of decline and recovery about every 80 years.

Researchers observe interdecadal (long-time) changes in sea-surface temperature, ocean circulation, and climate.

1967 1968 1969 1970 1971 1972 1973 1974 1975 1976 1977 1978

***Spawning biomass is an estimate of fish populations based on a sample of fish eggs and plankton eggs. A total catch should be a fraction of spawning biomass so that sufficient adults survive to reproduce.**

Sardine spawning biomass minimum at less than 10,000 metric tons.*

CalCOFI gets new research vessel when R/V **New Horizon** *joins fleet.*

by oceanographers, fisheries personnel, and meteorologists. Following the symposium the program's approach to the sardine question became more interdisciplinary and ecosystem-based. Fluctuations in fisheries yields could be understood only by studying the links between the ocean and the atmosphere and the variability of these systems within different scales of time and space.

The symposium focused on 1957 and 1958, a two-year period of fluctuation that is now known to have been an unusually strong El Niño event. During this time researchers observed anomalies in precipitation and fish stocks caused by rising ocean temperatures. Though the Pacific Ocean warmed by just 2°C, this increase caused dramatic changes. Hawaii had its first recorded typhoon. Seabirds died off the Peruvian coast. Along the Pacific's western rim, the tropical rainy season lingered six weeks beyond its normal term.

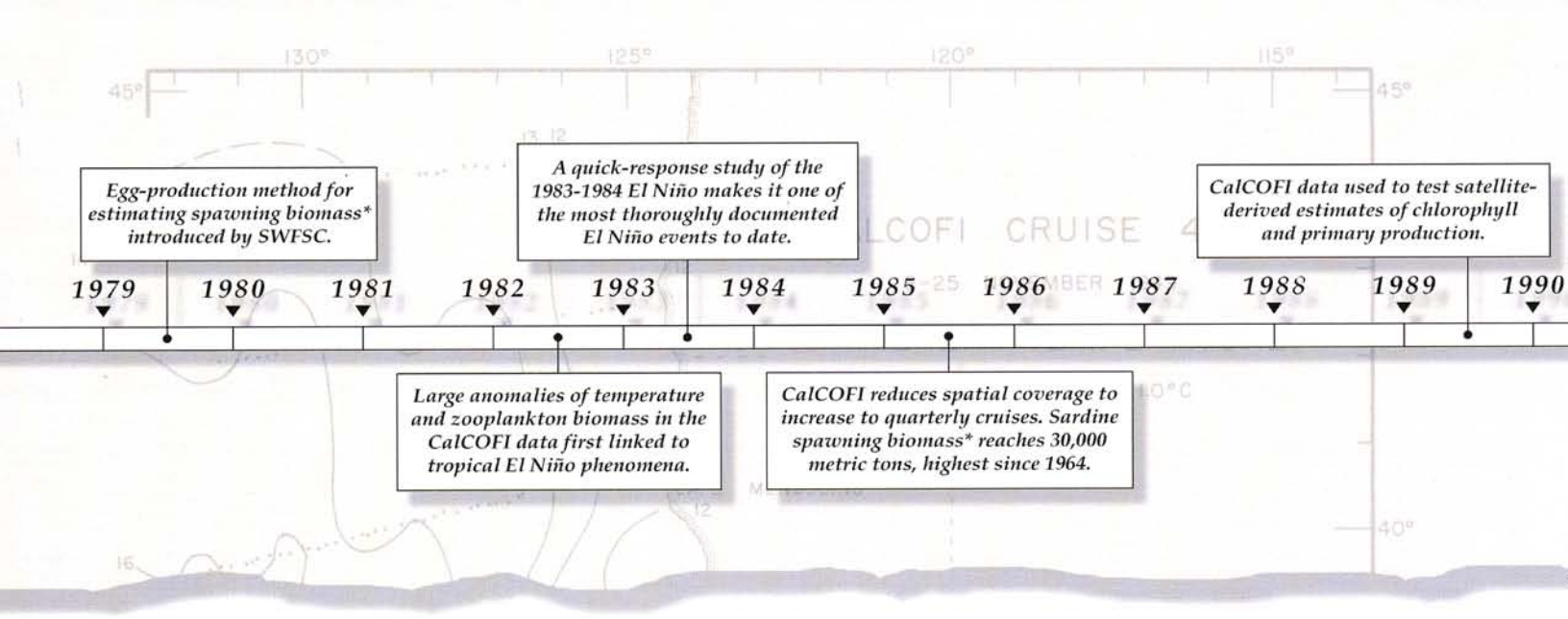
In 1969 CalCOFI researchers took cores from an undisturbed accumulation of ocean-bottom sediments off Santa Barbara. Fish scales found within the sediments represented a 1,800-year record of pelagic fishes. Andrew Soutar, a Scripps specialist in paleontology, identified and counted sardine scales as an index of past sardine biomass. He found that the sardine population fluctuates through a cycle of decline and recovery about every 80 years. Only once previously, about 800 years ago, had there been such an abundance of sardines as was seen in the 1920s and 1930s.

CalCOFI researchers conduct nine simultaneous hauls using this elaborate net system called a MOCNESS.

CalCOFI researchers suspected that a combination of natural cycle, environmental change, and overfishing caused the sardine fisheries collapse.

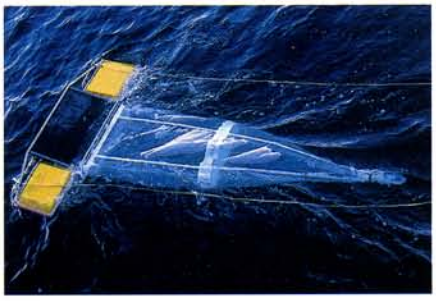
The program persists, as scientists continue to increase their understanding of the link between environment and fisheries. The goal of SWFSC scientists has been to apply knowledge of the early life history of fish to the assessment of fish stocks.

"The Southwest Fisheries Science Center, within the



context of CalCOFI, revolutionized fisheries stock assessment," says Elizabeth Venrick, a Scripps researcher and CalCOFI participant. The fisheries service had never embarked on such a comprehensive survey over such a large area. Rising to the challenge, SWFSC developed new techniques and equipment—now used worldwide—to examine spawning biomass, eggs and larvae, and juvenile fish populations.

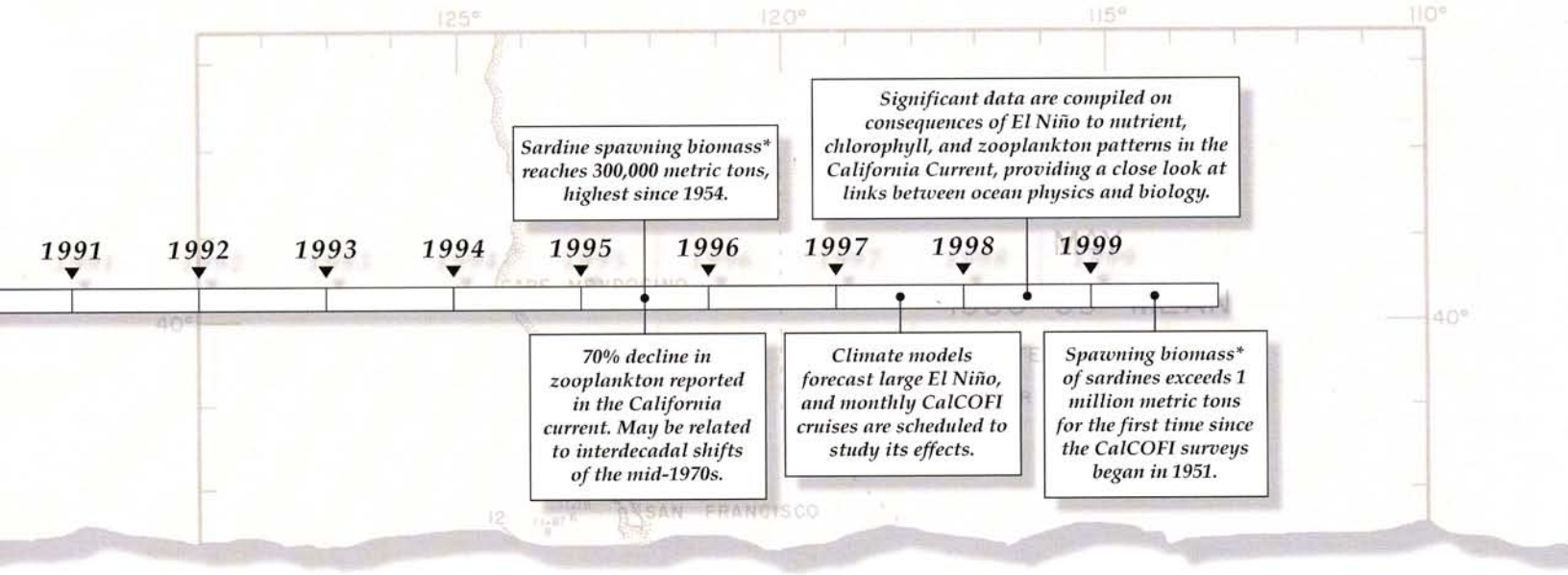
CalCOFI has established the importance of long-term ocean monitoring in detecting and studying environmental change. "CalCOFI is a continuous record going further back in time than almost any other marine data set," says Venrick. "Fifty years, by marine standards, is extremely long."



Above, The manta net (named for the animal it resembles) was developed at Scripps to collect fish eggs and larvae and other surface dwelling organisms as it skims the ocean. **Below,** A CTD rosette is deployed from R/V *Roger Revelle.*

Extensive data sets enable researchers to test the accuracy of prediction models and to define the normal range of conditions within the California Current. Once a baseline has been established, anomalies can be detected by viewing current oceanographic and biological conditions in the long-term context.

During the late 1970s researchers again observed dramatic changes in sea-surface temperature, ocean circulation, and climatology. The eastern Pacific became warmer, a phenomenon called a regime shift, impacting the climate and biodiversity along the California coast. "It's the biggest documented change that's taken place anywhere in the world's ocean, and the reason [it has been documented] is because we have this wonderful time series," says McGowan.



CalCOFI ocean monitoring was intensified during the 1997-1998 El Niño period, which was accurately predicted by Scripps researchers months in advance. This is one of the most informative studies conducted on the consequences of an El Niño to nutrient, chlorophyll, and zooplankton patterns, providing a close look at the links between ocean physics and biology. CalCOFI studies of the 1983-1984 and 1992-1993 El Niño events helped researchers predict how the ecology of the California Current would respond to this most recent El Niño.

Scripps graduate students Maria Mendez (left) and Alex Curtis (right) and visiting student Naho Horimoto (center) take a break on the deck of R/V *Roger Revelle*.

Scripps staff research associate Ed Renger organizes sample bottles in the wet lab on board R/V *Roger Revelle* during a recent CalCOFI cruise.

These days the sardine is making a comeback, and CalCOFI is not as extensive as it once was. Researchers from the program now make quarterly cruises to the current study area—from San Diego to Point Conception north of Santa Barbara—which encompasses about a third of the original area. But the history and importance of the program will sustain CalCOFI. The California Current is the best ecologically understood marine region in the world, a direct result of the CalCOFI program. According to MLRG director and CalCOFI researcher Michael Mullin, "The growing awareness of large-scale environmental change, which CalCOFI has been so important in documenting, has made the program a model that other institutions would like to emulate."

Student's Seabird Investigations Nest at CalCOFI

A faded letter written on yellowing paper is tacked to a bulletin board outside a classroom in Scripps's Ritter Hall. Written in the early 1960s by then-director Roger Revelle, it requires all Scripps students to participate in at least one California Cooperative Oceanic Fisheries Investigations (CalCOFI) cruise.

Scrawled as a coda are the words, "To my knowledge this mandate has never been rescinded." This note is from George Hemingway, CalCOFI coordinator, and he is only half joking. The mandate was never enforced, and not all students take part in CalCOFI cruises. But the students who do participate gain valuable experiences they may not have gotten otherwise, and they are able to conduct their own research.

Through the years more than a hundred students have gone to sea on CalCOFI cruises. Allowing students to utilize the wealth of assembled data while adding their own research findings to the ongoing database are important components of the program.

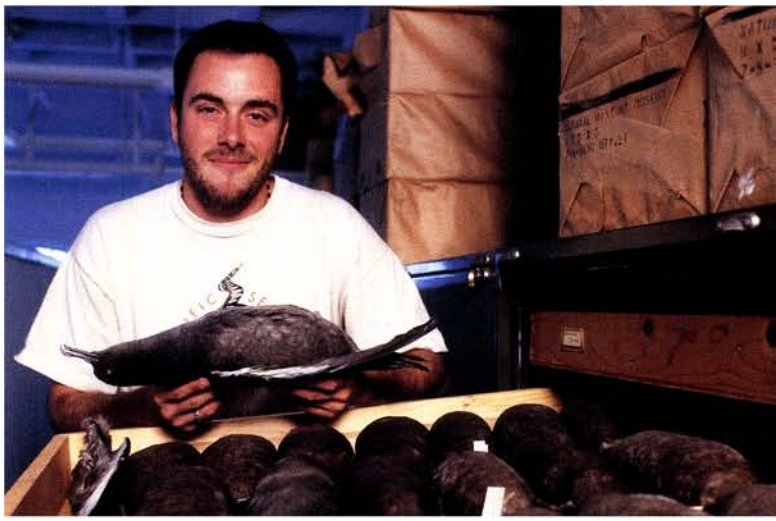
Graduate student David Hyrenbach, who has been studying seabirds at Scripps for six years, is a current participant. Continuing research on seabirds begun by Scripps professor John McGowan, Hyrenbach gathers new information during CalCOFI cruises.

His goal is to determine how documented declines in zooplankton abundance and rising ocean temperatures affect seabirds, which are top-level consumers. Between 1987 and 1994, McGowan and his associates found a 40-percent decrease in overall seabird abundance off southern California, mostly because of a 90-percent decline in the dominant cold-water species, the sooty shearwater. Since 1994, Hyrenbach has observed a continuing downward trend in total seabird abundance.

But the decline seems to be species specific. Hyrenbach explains, "There are basically two different types of local seabirds. Cold-water birds are highly migratory and come from as far away as Tasmania, Chile, and New Zealand. Warm-water, tropical birds come northward from Mexico and eastward from the central Pacific Ocean. While the numbers of cold-water birds have decreased, we've seen an increase in warm-water birds." There are two possible explanations, either the geographical distribution of seabirds is shifting or an actual decline in cold-water bird populations is occurring, according to Hyrenbach.

The waters off the southern California coast consist of temperature bands, swaths of water of different but predictable temperatures. Hyrenbach suspects a northward shift in warm-water temperature bands may be affecting seabird distributions within the study area. While the ocean is dynamic, the study area is fixed in space. "To a large degree, what we see or don't see is dictated by the different water masses that comprise our box [area of study]. If there is a northward warm-water shift, we may not see the cold-water birds because we're now sampling a warm-water area, not because they're dying off," Hyrenbach indicates.

Below, Scripps graduate student David Hyrenbach studies seabirds, such as this sooty shearwater *(Puffinus griseus)*, and occasionally provides samples to the San Diego Natural History Museum's Department of Birds and Mammals, where this picture was taken. **Top left,** Studies of variations in abundance of far-ranging birds like the black-footed albatross *(Phoebastria nigripes)* help document changes in ocean conditions in the North Pacific.



Similar studies have been conducted at the Gulf of the Farallones off San Francisco and Grey's Harbor in Washington State. The studies seem to agree: sooty shearwater populations have declined drastically since the mid 1980s. Hyrenbach is cautious when drawing conclusions, "This doesn't necessarily indicate that the population has decreased. These birds travel great distances to get here and could simply be going elsewhere or remaining in the Southern Hemisphere. But we do know that whatever is motivating these changes, it's operating over the entire west coast of the United States, and that's pretty powerful."

Hyrenbach credits the CalCOFI program with enabling him to conduct his research. "It has been wonderful to have access to this infrastructure. I'm working with 12 years of data, and there is no way I would have had the funds or time available to do this without CalCOFI. It has been invaluable to me, and I think it is helping a lot of other researchers who also use this information."